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PROGRAM

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NANTICOKE ENVIRONMENTAL MANAGEMENT PROGRAM ANALYSIS OF SO_2 EXCEEDANCE EVENTS IN THE HALDIMAND-NORFOLK REGION FOR 1975 - 1983

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1.0 INTRODUCTION

The Nanticoke industrial development is situated on the northern shore of Lake Erie in a primarily agricultural area. Located there are a 4,000 MW thermal generating station (T.G.S.), a 100,000 barrel/day oil refinery and a steel plant with a current production level of 1.2 million tons of steel per year. These plants, at present, are the only significant SO_2 emitters in the area and their emissions are significant enough to cause exceedances of the provincial air quality criteria (AQC) for some of the gases released.

Monitoring in the Haldimand-Norfolk region during the period from 1975-1983 has recorded 119 exceedances of the AQC (250 ppb hourly average) for sulphur dioxide (SO_2) out of more than 1,000,000 obtained measurements. This report presents a detailed analysis of each exceedance event, including a description of the synoptic conditions existing at that time, in order to identify the specific meteorological conditions associated with these exceedances. It should be noted here that there was only one exceedance of the daily AQC (100 ppb) and no exceedances of the annual AQC (20 ppb) for SO_2 during the period of network operations.

Atmospheric dispersion processes from point sources located along a shoreline are of a complex nature, primarily due to local circulations which are set up in response to the differential heating of the land and water. Lyons and Cole (1973) gave a detailed discussion of the implications of the lake breeze influence on local dispersion processes. Investigations of the transport of airborne material in a shoreline environment have been reported by Raynor et al (1974), Portelli (1978) and Misra (1980). Lyons and Cole (1973) found that plume fumigation due to lake breeze influence produced peak short term SO_2 concentrations in the vicinity of a power plant located near Lake Michigan. Hirt et al (1971) observed similar phenomenon on the shores of Lake Ontario. The Nanticoke Shoreline Diffusion Experiment (1978) confirmed plume fumigations in the Nanticoke area in response to both gradient on-shore flow and lake breeze circulations.

A brief description of the plume fumigation process on or near a shoreline is as follows: In spring and summer, the differential heating of land and water can cause local circulations (i.e. a lake breeze) to develop. A thermal internal boundary layer (TIBL) is formed when stable air over cooler water is advected over the warmer land surface in response to gradient or local flow. Plumes from tall stacks released into the stable lake air impinge the interface surface between the TIBL and planetary boundary layer (PBL) (Figure 1) and at some distance downwind are mixed into a highly turbulent lower layer, thereby producing high ground level concentrations (glc). The formation of the TIBL is greatly influenced by solar radiation and winds.

High glc's are also, however, possible in the absence of a TIBL. For example, Misra et al (1980) have described conditions leading to high glc's during the winter season at Nanticoke. In this situation, a convective boundary layer develops over an unfrozen lake as a result of cold airmass modification during advection over the relatively warm lake. The transfer of heat and moisture between the warm lake and the cold air forms a convective boundary layer over the lake. Advection of this convective boundary layer over the downwind shoreline forms a turbulent wake. Subsequent transfer of heat from the warm air to the cold land surface takes place until the convective turbulence dissipates at some downwind distance where mechanical turbulence prevails (see Figure 2). As a result of the above phenomenon, high glc's could be expected to occur closer to the source and at all hours of the day and night. In the Nanticoke area, the importance of background SO_2 levels cannot be ignored. Fleming (1980) has shown that the long-range transport of SO_2 across Lake Erie during the winter period may also increase SO_2 levels in the Nanticoke area.

The general climatology of the Haldimand-Norfolk region is greatly influenced by Lake Erie. During spring and summer, the lake temperature is lower than the land temperature. Consequently, under weak pressure gradients and strong solar insolation, a lake breeze will develop. A thermal internal boundary layer forms as the cold lake air is advected over land and heated from below. Similarly, TIBL can form if the on-shore flow is due to general synoptic conditions.

Local wind flow patterns, land/lake temperatures and mixed layer heights are some of the important meteorological control factors in the region. A full complement of climatic statistics for these parameters has been derived on a monthly basis from the records of the Jarvis meteorological tower (located 12 km inland from the shoreline) and an acoustic sounder (located 6 km north of the shoreline). The air temperature statistics (10 m level of the Jarvis met. tower) and the wind statistics (85 m level of Jarvis met tower) are based on 9 years (1975 to 1983) of hourly observations (Table 1 and Figures 3 and 4 respectively). Monthly mean surface lake temperatures obtained from the Atmospheric Environment Service (Table 2) are based on 16 years of lake temperature data (1966-1981) collected by remote sensing techniques. Figure 5 shows the behaviour of average daily mixed layer heights which were determined by acoustic sounder from 1979 to 1981 for the four seasons in the Nanticoke area. Mixed layer heights grow rapidly during the spring and summer. During winter the growth rate is much slower.

A detailed description of the climatology in the Haldimand-Norfolk region has been previously reported (Kiely and Sahota, 1981).

2.0 REGIONAL SO_2 AIR QUALITY IN THE HALDIMAND-NORFOLK REGION

Since 1975 there has been extensive SO_2 monitoring within 40 km of the Nanticoke T.G.S. (Figure 6). The number of monitoring stations varied between 16 and 20. Figure 7 shows the annual variations of SO_2 levels exceeding 100 ppb over the 1975-1983 period. There have been in excess of 1,000,000 hours monitored over the nine-year period from the combined sites and only 119 (hourly averaged) exceedances of the AQC (250 ppb) were recorded. Generally, the SO_2 concentrations are well below 100 ppb. 1977, however, was an unusual year; there were $>$ 400 hours in which the SO_2 levels exceeded 100 ppb and in excess of 150 hours were observed during the winter period. Long-range transport of air pollutants (LRTAP) may have been the cause, due to a relatively high frequency of winds (53%) from the southwest and west-southwest sectors during January 1977 and a very cold winter experienced by the central U.S..

Figures 8a and 8b show the diurnal variation in the number of hours of SO_2 greater than 100 ppb annually and for each season (winter, spring, summer and fall)* from 1975 to 1983. In the spring and summer, elevated SO_2 levels have been observed between 1000 and 1800 EST. The highest total number of hours in excess of 250 ppb (all of which were recorded in the daytime) occurred during summer. In the fall season, hours with poor air quality were observed during both daytime and nighttime, with a slightly higher frequency of occurrence during the daytime hours. In winter, the hours with high SO_2 levels were approximately evenly distributed throughout the 24-hour period.

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*Winter = December to February; Spring = March to May; Summer = June to July; Fall = September to November.

The results of the SO_2 exceedance rose (Figure 9) suggest that in most cases the generating station is the source of the short-term elevated SO_2 levels ($>$250 ppb) since the monitors recording these high SO_2 concentrations were almost always downwind of the power plant. It should be noted here that while the Texaco refinery also emits SO_2, its emissions are only 1/30 those of Ontario Hydro and are, therefore, insignificant in comparison. Hourly exceedances occurred during the period from 1975 to 1978 although the refinery did not begin operations until November 1978.

Over the nine-year monitoring period, there has only been 1 exceedance of the daily (100 ppb) AQC. Fleming (1980) attributed this exceedance episode to long-range transport of a significant amount of SO_2 across Lake Erie. Since there were high SO_2 levels throughout the entire monitoring network, we agree that long-range transport was, indeed, responsible for this daily exceedance.

3.0 SEASONAL DISTRIBUTION OF EXCEEDANCE EVENTS

The seasonal distribution of hours recorded in excess of 250 ppb suggests that there are different mechanisms causing these high glc's. A detailed analysis of each exceedance event and the probable mechanism responsible for it is presented in the Appendix.

During the period from 1975 to 1983, of the 119 exceedances of the hourly AQC (250 ppb), 103 were non-coincident. Exceedances occurring on the same day were, therefore, considered as one event. In total, over the nine-year period there were 74 events distributed seasonally as follows: summer 32; fall 20; spring 15; and winter 7. An analysis of the exceedances which occurred during the months of May through August from 1975 to 1977 has been previously documented by the Atmospheric Environment Service. For the purposes of completeness, these events have also been included in the present report.

3.1 SUMMARY OF METEOROLOGICAL CONDITIONS LEADING TO HIGH SO_2 LEVELS DURING SPRING AND SUMMER

Shoreline meteorology is influenced by the temperature difference between land and lake surfaces. Under certain meteorological conditions, a pressure gradient may be established by the temperature difference. If the prevailing synoptic conditions are such that the synoptic gradient flow is light, the pressure gradient due to local density difference is the dominant force and a lake breeze is established. In the following analysis of meteorological conditions existing prior to and during the fumigation events, emphasis has been given to determining whether or not a lake breeze was established on the day when the fumigation event occurred.

The criteria for the selection of days on which "a lake breeze was probably established" were as follows:

1) daytime temperature of the land exceeding that of the lake
2) no frontal passages occurring six hours prior to the fumigation event
3) surface wind direction shifting from off-shore during the early morning hours to on-shore at some time during the day
4) surface wind speeds in the 0-20 km/hr. range
5) sunny day, generally free of clouds
6) weak synoptic pressure gradient

Days in which criteria 1 or 2 were not fulfilled were excluded from further analysis. Each day accepted for consideration on the above basis was given a lake breeze index (LBI) based upon dimensional analysis. The index was then compared with the observed charts for the day to determine if, indeed, there was a lake breeze influence. For this purpose, a lake breeze index formula as modified by Lyons (1972) was selected. The index is defined as follows:

$$LBI = Vg^2/Cp \, \Delta T$$

Vg is the geostrophic wind speed taken from the 1800 GMT surface synoptic map

Cp is the specific heat of dry air

ΔT is the difference between maximum daily air temperature and maximum water temperature

If the $LBI < 10$, a lake breeze is expected to occur (Lyons 1972).

Mean daily air temperatures were extracted from monthly weather summaries for the Simcoe weather station. We chose the Simcoe station instead of the closer to shoreline Jarvis meteorological tower because on lake breeze days, the maximum air temperature recorded at Simcoe would be less likely affected by the lake breeze influence. Daily water temperatures were obtained from the Atmospheric Environment Service, as were the surface synoptic charts. An LBI was calculated for each fumigation event which occurred during the months from March to August. Data pertaining to these episodes are summarized in Table 3 page 13. Meteorological conditions associated with each event are discussed in the Appendix.

On six of the 29 occasions in which the LBI was less than 10, the lake breeze failed to develop. Closer examination of these events revealed that on five of the six occasions, moderate gradient flow masked any lake breeze influence. For the event on July 27, 1979, although the pressure gradient was weak enough, the lake/land temperature difference was only 1°C. Using the LBI > 10 as the development criterion, more than 80% of the 29 days found to have a potential lake breeze did, in fact, develop a lake breeze. The LBI appears to be, therefore, a good predicator of lake breeze occurrence.

Of the 47 SO_2 events which occurred during spring and summer; 8 coincided with frontal passages; 13 with moderate gradient flow; 1 with unstable conditions associated with a low pressure system; 1 with calm conditions and 1 event was eliminated because of unavailable meteorological data. The remaining 23 events occurred on days with a lake breeze influence. It is of interest to note that the lake/land temperature difference ranged from 3° to 10°C on days influenced by a lake breeze. The onset time of the lake breeze showed a peak between 0800 to 1100 EST although on days when the gradient flow was weakening, late afternoon onsets did occur (see Figure 10).

3.2 SUMMARY OF METEOROLOGICAL CONDITIONS LEADING TO ELEVATED SO_2 DURING THE WINTER SEASON

During the winter months of December to February (1975 to 1983), seven hourly AQC exceedances occurred in the Haldimand-Norfolk region monitoring network. The synoptic conditions at the time of the exceedances are described in detail in the Appendix. Meteorological conditions were similar throughout 6 of the 7 events. A deep low pressure system centred over the upper Great Lakes produced strong south-southwesterly to southwesterly flow over the Nanticoke region. During the remaining exceedance event, a high pressure system centred to the south of the lower Great Lakes produced a west-southwesterly flow over the Nanticoke region. Elevated SO_2 concentrations were of short duration (usually 1 hour) and were confined to those monitors located within 10 km of the shoreline in a north-northeasterly to northeasterly direction (Table 4). Five of the seven winter episodes occurred prior to the commissioning of the Texaco refinery in November 1978. Since all values exceeding the AQC during these five events were recorded by monitors downwind of the Ontario Hydro generating station, it is concluded to be the most likely major source of the pollutant. During the remaining exceedance events (January 1980 and February 1982), when both Ontario Hydro and Texaco were in operation, the contribution made by Texaco to the glc of SO_2 was small compared to that made by Ontario Hydro. Although long-range transport is known to have a significant impact on the background levels of SO_2 during the winter period in the Nanticoke region, fumigations of short duration are mainly the result of local industry.

Six of the seven events in the winter period occurred either during the late evening or early morning hours. High winds associated with the winter exceedance events may have caused impingement of the Nanticoke T.G.S. plume. However, it should be noted that on five occasions, Lake Erie had an open water surface. As mentioned in Section 1.0, convective turbulence (due to the transfer of heat from the warm air to the cold land surface) within the turbulent wake could result in elevated glc's of SO_2 in winter.

The only daily exceedance of the AQC (100 ppb) of SO_2 occurred during January, 1977. The daily average concentration was 106 ppb at station N15. Steady winds from the SW and high SO_2 concentrations recorded by all monitors between 0100 and 0400 EST suggests LRTAP as the cause of this episode.

3.3 SUMMARY OF METEOROLOGICAL CONDITIONS LEADING TO HIGH SO_2 DURING FALL

The fall season in the Haldimand-Norfolk region is characterized by strong SSW to W winds. The water temperature is near its maximum in late summer (22°) and since Lake Erie is relatively shallow, its temperature starts to decrease by mid-September (19°C). Land and water temperature are almost at equilibrium, thus inhibiting the generation of the lake breeze. In the lower atmospheric layer, predominantly near neutral stability conditions are observed.

There were a total of 20 exceedance events during the fall season (Table 5). Three of the exceedance events (September 1, 1978, September 30, 1980 and September 30, 1982) coincided with lake breeze influence. On eight other occasions, mechanical turbulence from the strong winds ($>$30 km/hr) brought the plume to the ground. Eight of the remaining nine exceedance events were recorded during the daytime period (1100 to 1700 EST). Winds at the time of exceedance were light to moderate. It is possible that a temperature inversion layer trapped the plume in a well mixed layer. Turbulent eddies within this layer could have brought the plume to the ground. The exceedance event of September 19, 1978 occurred during calm wind conditions.

4.0 SUMMARY

This report examined the general meteorological conditions associated with elevated SO_2 levels in the Haldimand-Norfolk region from 1975 to 1983.

Climatological analysis showed that the lake/land temperature difference is maximum from May to August. During these months, TIBL formation coincides with high glc's of SO_2. Synoptic flow from the southerly quadrant and high surface air temperatures enhance the development of the TIBL. The predominant wind direction in the Haldimand-Norfolk region is from the SSW to W in fall, SSW to NW in spring SSW to SW in summer and W in winter.

Mixed layer heights show a rapid growth rate during spring and summer. During winter, the growth rate is much slower. There is little difference between average maximum height for all seasons. This is due to the lake effect.

Through the years 1975 to 1983, the violations of the AOC for SO_2 as reported by the SO_2 monitoring network in the Haldimand-Norfolk region were very few (only 119 recorded violations out of more than 1,000,000 monitored hours).

In spring and summer, weak pressure gradients and clear skies, coupled with land temperatures exceeding those of Lake Erie, favour the development of the lake breeze. On 23 occasions, SO_2 exceedance events occurred under the influence of the lake breeze. In the winter period, low pressure systems centred over the upper Great Lakes produce strong southwesterly flows in the Nanticoke area. High winds inhibit plume rise and lead to elevated glc's of SO_2 during the winter season. In the fall season, SO_2 exceedance events are associated with lake breeze influence, mechanical turbulence from strong winds and plume trapping due to temperature inversion layers.

When SO_2 exceedances are reported, they have been found to lie downwind of the Nanticoke TGS and the Texaco refinery. Of the two industries, the Ontario Hydro generating station emits 30 times more SO_2 (on a yearly average) than the refinery and it is considered, therefore, the major contributor to high SO_2 levels in the Haldimand-Norfolk region. Upwind monitors (Long Point for southerly flows) have not recorded any SO_2 exceedances but there is evidence that sources south of the lake may influence the background levels at Long Point due to long range transport, especially during the winter period.

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TABLE 1

Mean Surface Air Temperatures (10 m level Jarvis Met. Tower) (1975-1983)

Month	Mean Temperature	Maximum Temperature	Minimum Temperature
January	-7.5	-0.7	-13.3
February	-5.6	2.5	-14.0
March	0.7	11.4	-7.7
April	7.2	16.8	-0.7
May	13.6	22.7	2.1
June	18.9	26.7	11.1
July	21.5	28.7	15.1
August	20.5	26.2	13.7
September	15.8	26.1	5.9
October	8.5	16.5	1.9
November	4.0	13.0	-2.4
December	-2.8	3.0	-7.0

Air temperatures are in degrees C

TABLE 2

Mean Lake Erie Water Temperatures (1966-1981)

Month	Mean Temperature	Maximum Temperature	Minimum Temperature
January	N/A	N/A	N/A
February	N/A	N/A	N/A
March	N/A	N/A	N/A
April	3.5	5.4	1.9
May	9.4	13.0	5.7
June	16.8	19.5	13.6
July	21.1	21.6	19.8
August	21.8	22.0	21.4
September	19.7	21.2	17.5
October	14.4	17.1	11.7
November	9.1	11.4	6.5
December	3.8	6.1	1.7

Water temperatures are in degrees C

TABLE 3

Data Summary for Potential Lake Breeze Occurrence during March to August (1975-1983)

Date	Time (EST)	Monitor Location	Recorded Conc (ppb)	Wind Speed km/hr	Wind Direction	Land Temp C	Lake Temp C	Calc Lake Breeze Index	Calc Vg (km/hr)	10 m level Speed (km/hr)	Type of Influence
750422	1200	N08	420	11	SSW	N/A	4	N/A	10	9	insufficient data
750325	1500	NNE17	310	18	S	N/A	11	N/A	29	15	frontal activity
750716	1500	NNE15	300	16	SSW	28	21	2.4	15	17	lake breeze
750718	1400	NNE09	330	18	SW	24	21	10.3	27	26	gradient flow
750802	1300	NNE15	260	25	SSW	29	22	2.4	9	15	lake breeze
		NNE15	330								
760618	1100	NNE15	280	11	S	27	17				
	1200	NNE15	400	13	S	27	17	15.6	40	16	gradient flow
	1500	N08	310	18	S	27	17				
760622	1500	N08	420	14	S	26	18	4.2	14	13	lake breeze
	1600	N08	370	11	SSE	26	18				
760709	1700	NNW15	300	16	SSE	25	21	0.3	4	17	lake breeze
760728	1200	WNW20	650	8	E-ESE	27	22				
	1300	WNW20	320	15	ESE	27	22	3.4	15	15	lake breeze
	1500	NNW08	370	8	SSE	27	22				
760814	1600	NNW11	280	10	SE	24	22	-	-	-	frontal activity
760819	1600	NNW15	310	11	SSE-S	26	22	5.5	16	16	lake breeze
770321	1800	NNE15	250	6	E	5	0	-	-	-	frontal activity
770522	1500	NNE17	370	28	SSW	29	11	6.9	38	27	gradient/lake breeze
770524	1400	NNE17	270	19	SSW	28	11	-	-	-	frontal activity
770628	1300	NNW11	300	11	SE-SSE	28	18				
	1400	NNW08	590	11	SE	23	18	2.2	12	14	lake breeze
	1500	NNW08	280	11	SE	23	18				
	1600	NNW15	360	10	SSE	23	18				
770826	1300	NNW08	270	11	SSE	24	22	26.9	27	14	gradient flow
770831	1300	NNE17	330	17	SSW	27	21	-	-	-	frontal activity
780419	1000	NNW08	280	12	SE	14	4				
	1100	NNW08	270	13	ESE	14	4	12.8	41	20	low pressure cell
		NNW15	300								
780518	1300	NNE09	270	21	SSW	15	10	0.2	5	19	lake breeze
780601	1500	NNE16	360	20	SSW	19	18	-	-	-	frontal activity
780606	1500	NNE09	360	21	SSW	21	15	7.0	23	24	gradient flow
	1600	NNE09	710	23	SSW	21	15				
780623	1500	NNE10	390	20	S	21	18	0.1	2	15	lake breeze
	1600	NNE10	300	19	S	21	18				
780707	1400	NNE16	270	24	SSW	30	20	3.8	20	23	gradient/lake breeze
780717	1700	NNE10	310	24	SSW	26	21	0.2	4	16	lake breeze
780801	1400	NNE10	280	31	SSW	27	22	8.1	23	23	gradient flow
780802	1600	NNE10	320	25	SSW	29	22	4.3	20	28	gradient flow
780815	1400	NNE10	270	25	SSW	29	22	-	-	-	frontal activity

TABLE 3 con't

Data Summary for Potential Lake Breeze Occurrence during Spring and Summer (1975-1983)

Date	Time (EST)	Monitor Location	Recorded Conc (ppb)	Wind Speed km/hr	Wind Direction	Land Temp C	Lake Temp C	Calc Lake Breeze Index	Calc Vg (km/hr)	10 m level Speed (km/hr)	Type of Influence
790406	1200	E05	250	75	W	1	3		90	66	gradient flow
790502	1200	NNW08	310	10	SSE	13	6	9.8	20	15	lake breeze
		NNW11	300								
790505	1400	NNE10	270	24	SSW	8	7	-	-	-	frontal activity
	1500	NNE10	260	29	SSW	8	7				
790727	1200	WNW03	360	calm	calm	23	22				
	1300	NNE09	400	calm	calm	24	22				
		NNE16	250					1.0	5	5	calm conditions
		N07	360								
	1400	N07	240	calm	calm	24	22				
		NNE10	310								
800616	1600	NNE16	410	16	S-SSW	18	17	83.0	33	19	gradient flow
800714	1200	NNE16	410	16	S-SSW	28	21	0.8	6	26	lake breeze
		NNE20	310								
800718	1600	N15	240	16	S	28	21	3.6	4	23	lake breeze
810410	1600	NNE16	420	25	SSW	17	3	8.1	87	26	gradient flow
810504	1600	NNE10	280	11	S	21	6	1.7	18	15	gradient/lake breeze
810508	1200	NNW08	270	17	ESE	17	7	3.5	21	19	lake breeze
810709	1400	N07	270	15	S-SSW	26	20	7.6	24	15	gradient flow
	1500	N07	450	12	SSW	25	20				
810822	1300	NNE05	290	10	S-SSW	26	22	3.2	13	13	lake breeze
810826	2200	E05	260	10	ESE	25	22	1.6	5	5	lake breeze
820714	1600	NNE10	270								
		NNE16	352	7	SSW	27	21	0.1	2	7	lake breeze
		NNE20	280								
	1700	NNE16	417								
		NNE20	300								
820716	1500	NNE20	270	13	SSW	30	21	0.2	5	6	lake breeze
830429	1200	NNW08	232	12	SSE	14	6	1.3	3	11	lake breeze
	1300	NNW08	262								
830513	1200	W13	231	21	E	22	10	-	-	-	gradient flow
830622	1100	NNW08	438	11	SSE	28	19	0.1	4	12	lake breeze
	1200	NNW08	411	16	SSE						
830814	1500	NNW08	313	10	SSE	23	22	10.2	12	10	gradient flow
830817	1300	NNE20	291	18	SSW	28	22	17.0	39	17	gradient flow

TABLE 4

Data Summary for SO2 Exceedance Events during Winter Season (1975-1983)

Date	Time (EST)	Monitor Location	Recorded Conc (ppb)	Wind Speed km/hr	Wind Direction	Ice Covered
760119	2100	NNE09	250	43	SSW	No
		NNE10	260			
(760128	2300	NNE09	280	43	SW	Yes
760129)	0100	NE10	260	30	SW	
771223	0500	NNE09	270	42	SSW	
	0600	NNE09	290	42	SSW	No
	1100	NNE09	260			
780126	1900	NNE09	310	94	SW	Yes
781213	0300	NNE09	350	47	SW	No
800107	0500	NNE05	300	66	SSW	No
	0600	NNE05	270	63	SSW	
820210	1200	NNE19	436	23	WSW	No

760128 and 760129 are considered as 1 event

TABLE 5

Data Summary for SO2 Exceedance Events during Fall Season (1975-1983)

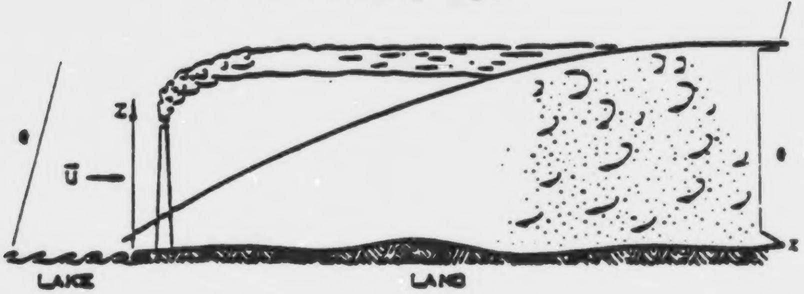
Date	Time (EST)	Monitor Location	Recorded Conc (ppb)	Wind Speed km/hr	Wind Direction	Land Temp C	Lake Temp C
751027	1300	NE10	260	18	SSW	N/A	12
751101	0600	NNE09	450	36	SW	N/A	11
		NNE15	340				
	0700	NNE09	450	39	SW	N/A	11
	0800	NNE09	500	36	SW	N/A	11
761011	1400	NNW08	280	15	SSE	13	15
	1500	NNW08	290	15	SSE	13	15
761015	0200	NNE09	270	32	SSW	17	14
		NNE15	290				
	0400	NNE09	260	32	SSW	17	14
780901	1700	N07	260	17	S	25	21
780919	2000	W13	260	calm	calm	15	19
780927	1100	NNE09	270	34	SSW	21	18
781030	1200	N07	390	11	S	13	12
800930	1300	NNE09	250	28	SSW	23	17
801120	1400	NNE16	370	31	SSW	6	8
811014	1100	NNE10	300	18	SSW	14	14
	1200	NNE39	300	16	SSW	14	14
811020	1000	NNE09	320	41	SW	14	13
	1100	NNE09	320	45	SSW	14	13
	1300	NNE10	280	44	SSW	14	13
811024	1400	NNE10	280	13	SSW-SW	5	13
811025	1500	N07	260	11	SSE-S	11	13
811110	1200	NNW08	300	12	SSE	4	10
	1400	N15	330	14	SSE-S	4	10
(811126	2400	NNE05	310	50	SSW	13	7
811127)	0200	NNE09	1130	54	SW	13	7
	0400	NNE09	320	58	WSW	13	7
820917	1600	NNE09	273	14	SSW	17	16
820930	1400	NNE16	256	13	SSW	22	17
821111	2400	NNE05	280	45	SSW	14	5
830921	0200	NNE05	320	35	SW	15	18

811126 and 811127 are considered as 1 event

780901, 800930 and 820930 are associated with lake breeze influence

Figure 1

Fumigation Due to Plume Mixing into an Internal Boundary Layer

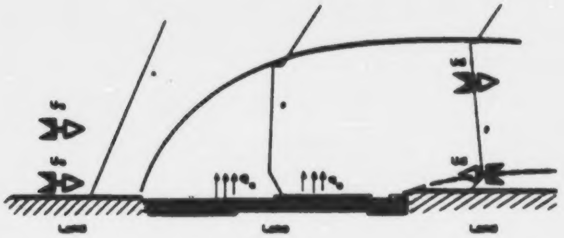


$\bar{u}$ mean wind   x downwind distance

Z plume height   θ potential temperature

Figure 2

Schematic Representation of Modification of Cold Airmass During Advection Over Warm Lake



U_u Upwind wind U_d Downwind wind

Q_o heat flux q_o moisture flux

θ potential temperature

Figure 3

Annual Wind Rose for 85m Winds at Jarvis Met. Tower 1975-1983

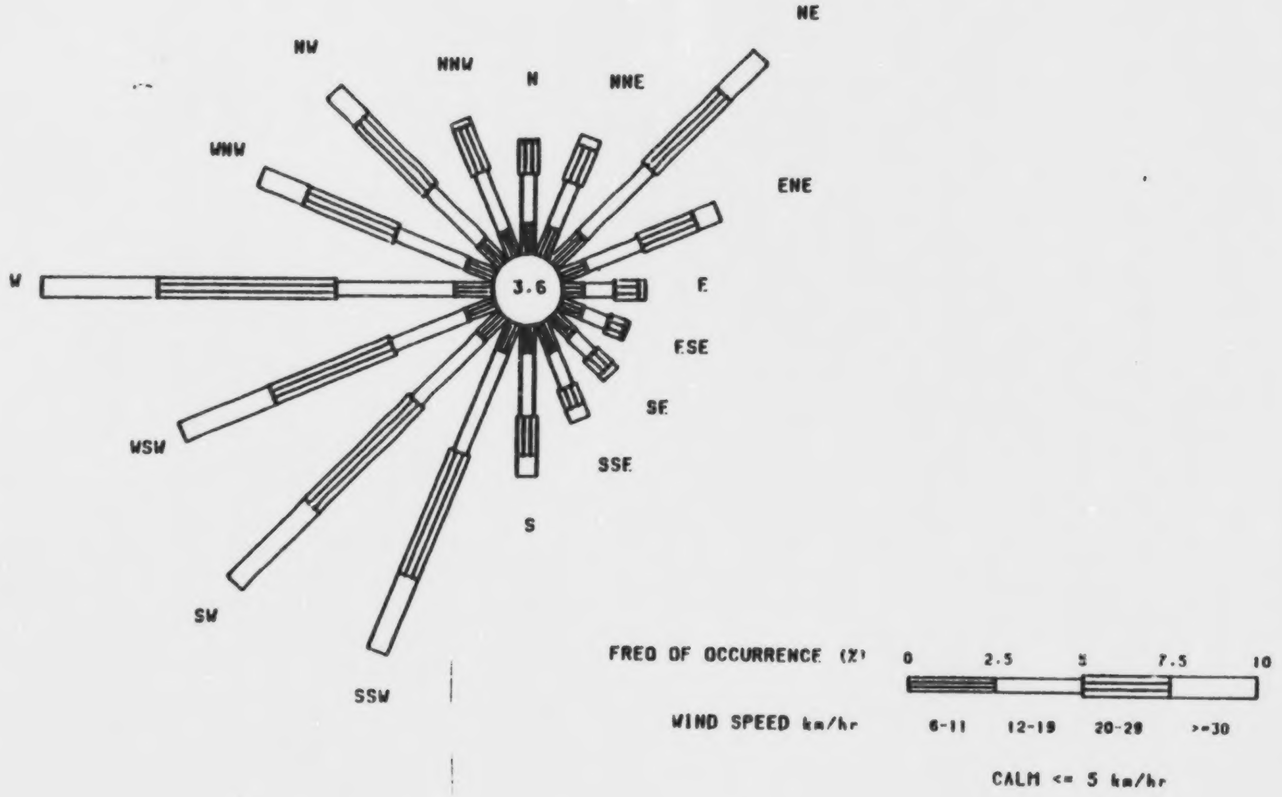


Figure 4

Seasonal Wind Roses for 85m Level Winds at Jarvis Tower 1975-1983

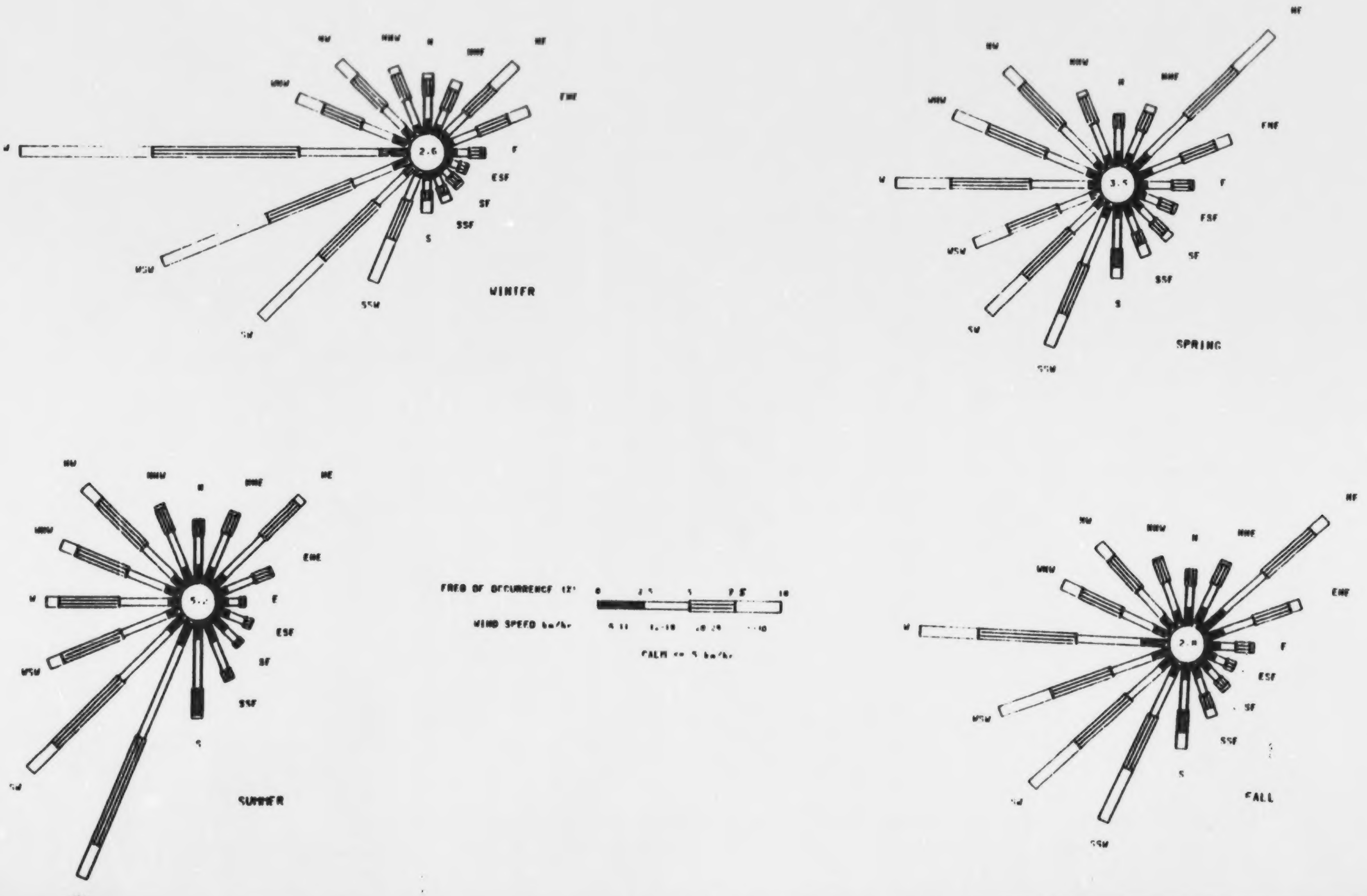


Figure 5 Seasonal Distribution of Hourly Averaged Boundary Layer Heights (BLH) According to Wind Direction (1979-1981)

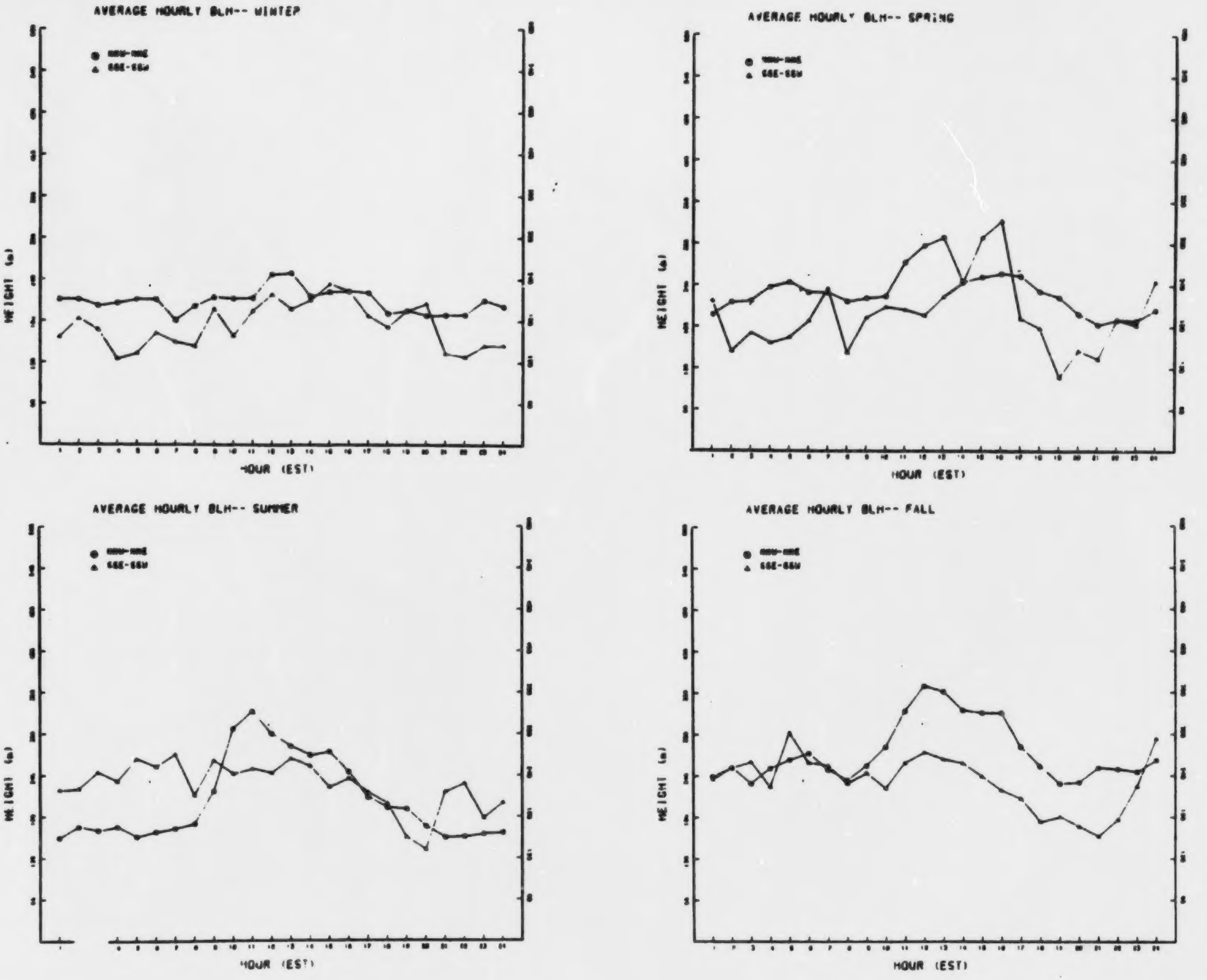


Figure 6

SO2 MONITORING NETWORK IN THE HALDIMAND-NORFOLK REGION

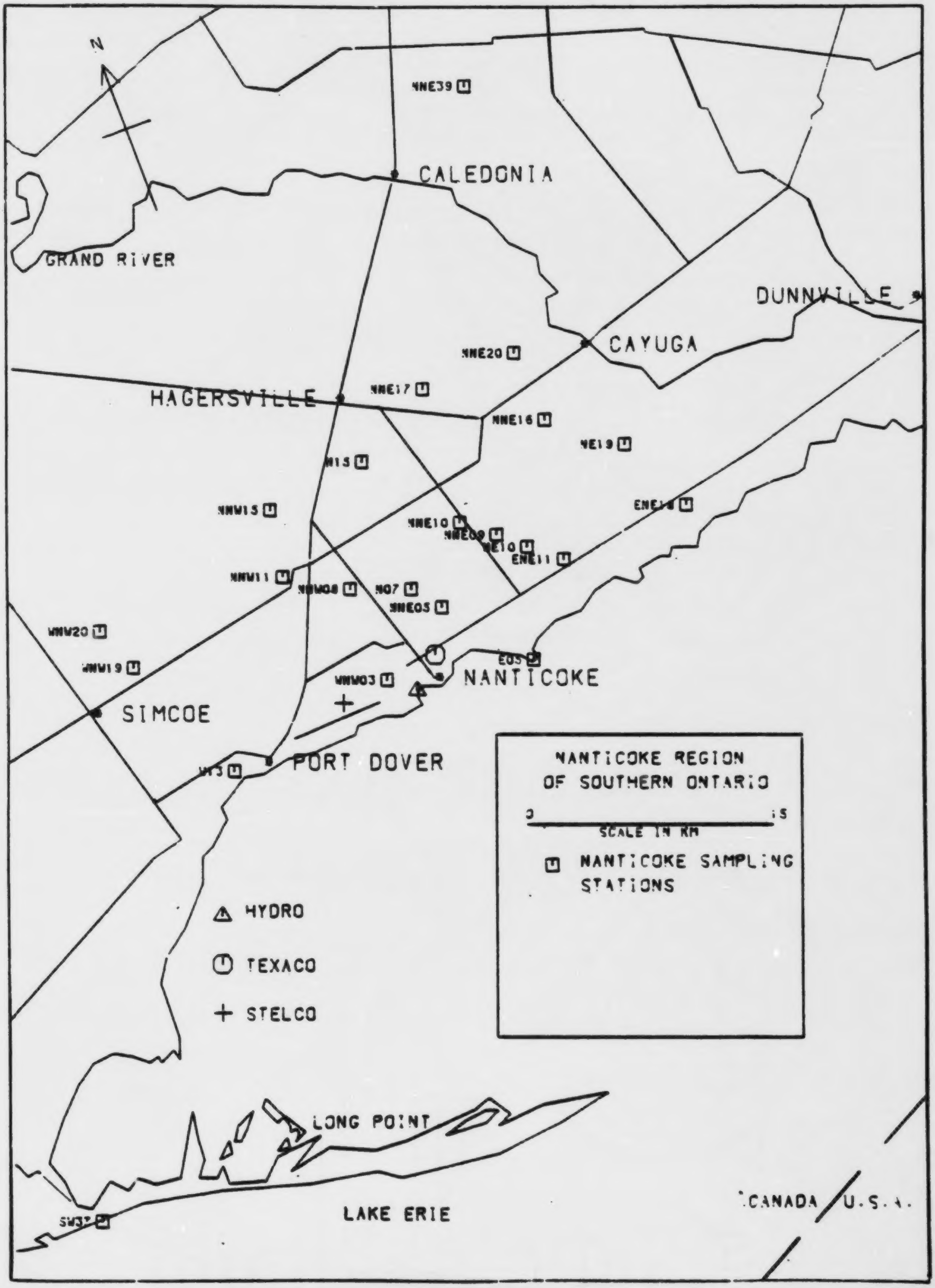


Figure 7

Annual Variation of SO_2 Levels Exceeding 100 ppb

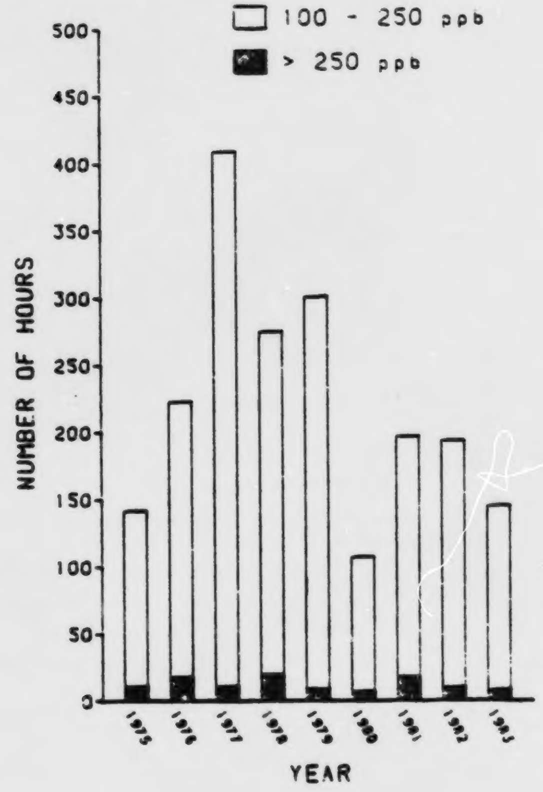


Figure 8a

Diurnal Variation of SO_2 Levels Exceeding 100 ppb

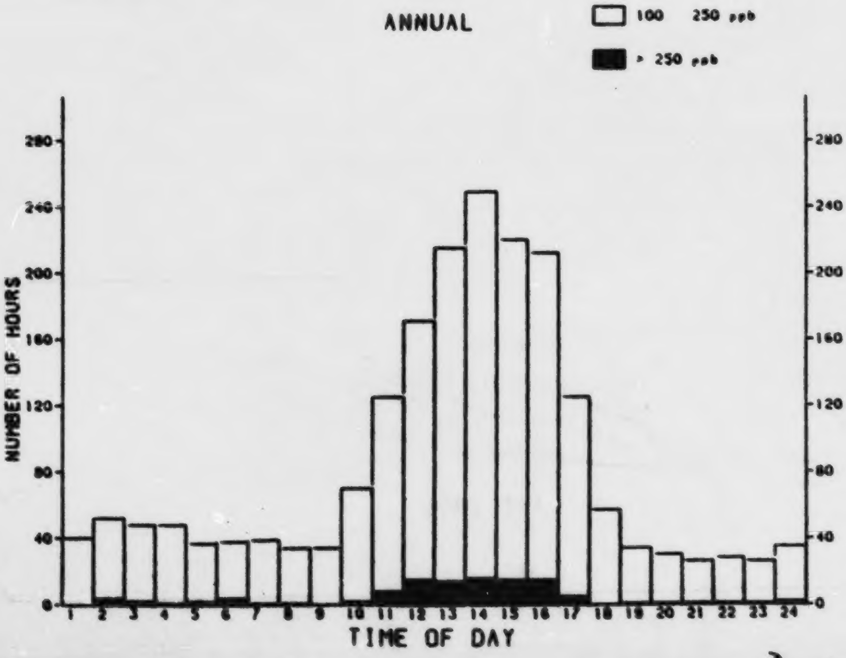


Figure 8b

Diurnal Variation of SO_2 Levels Exceeding 100 ppb According to Season

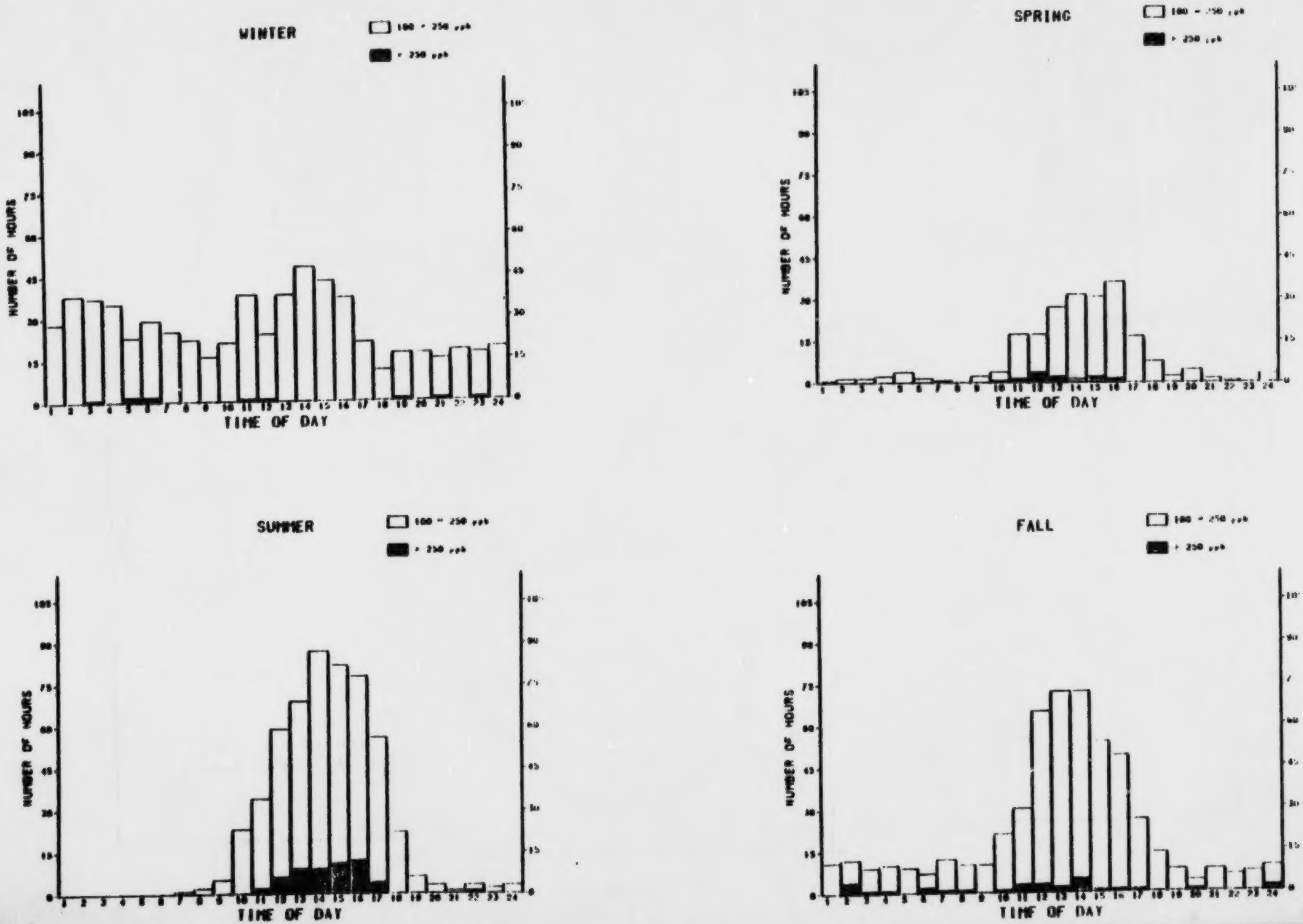
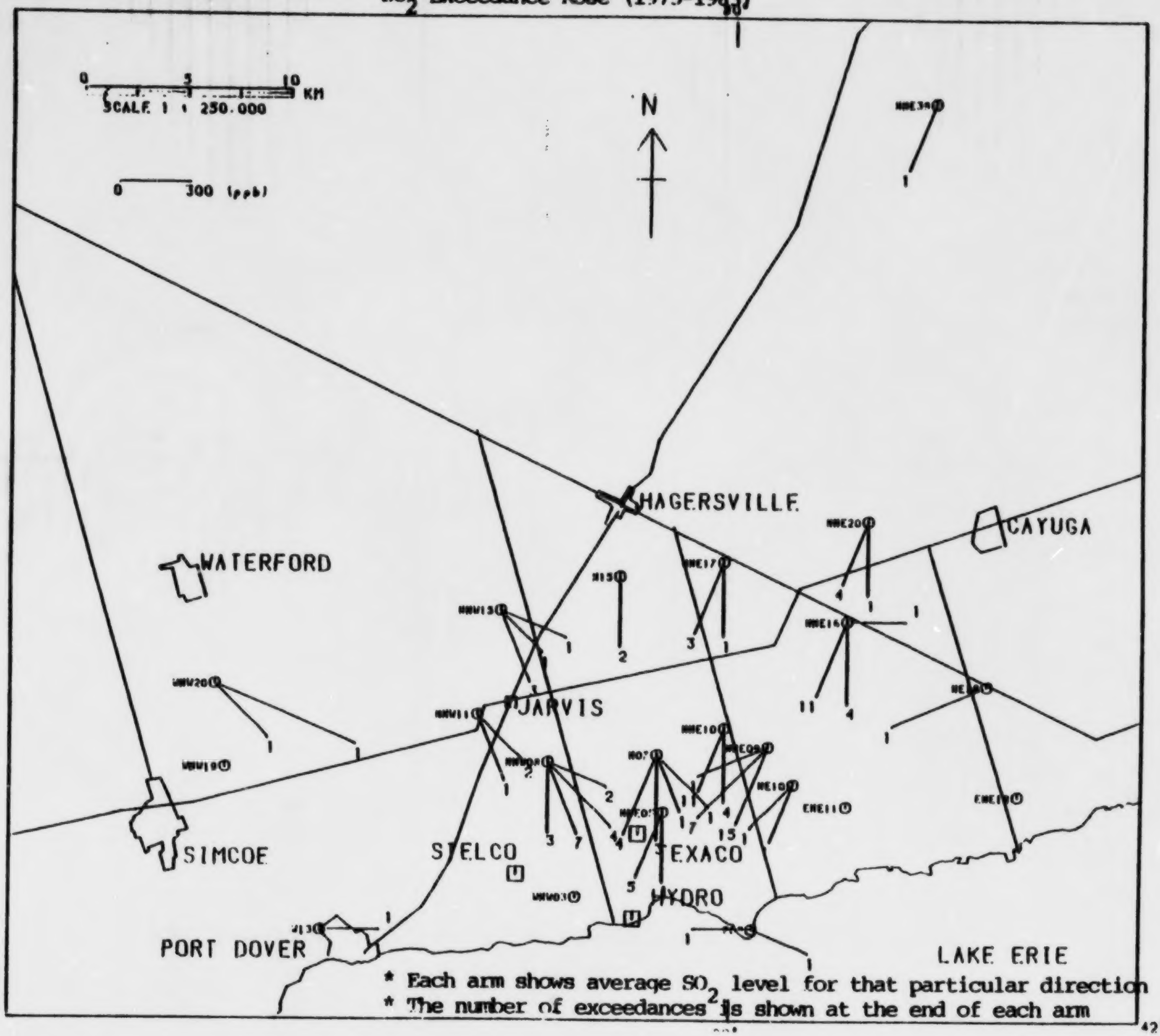


Figure 9

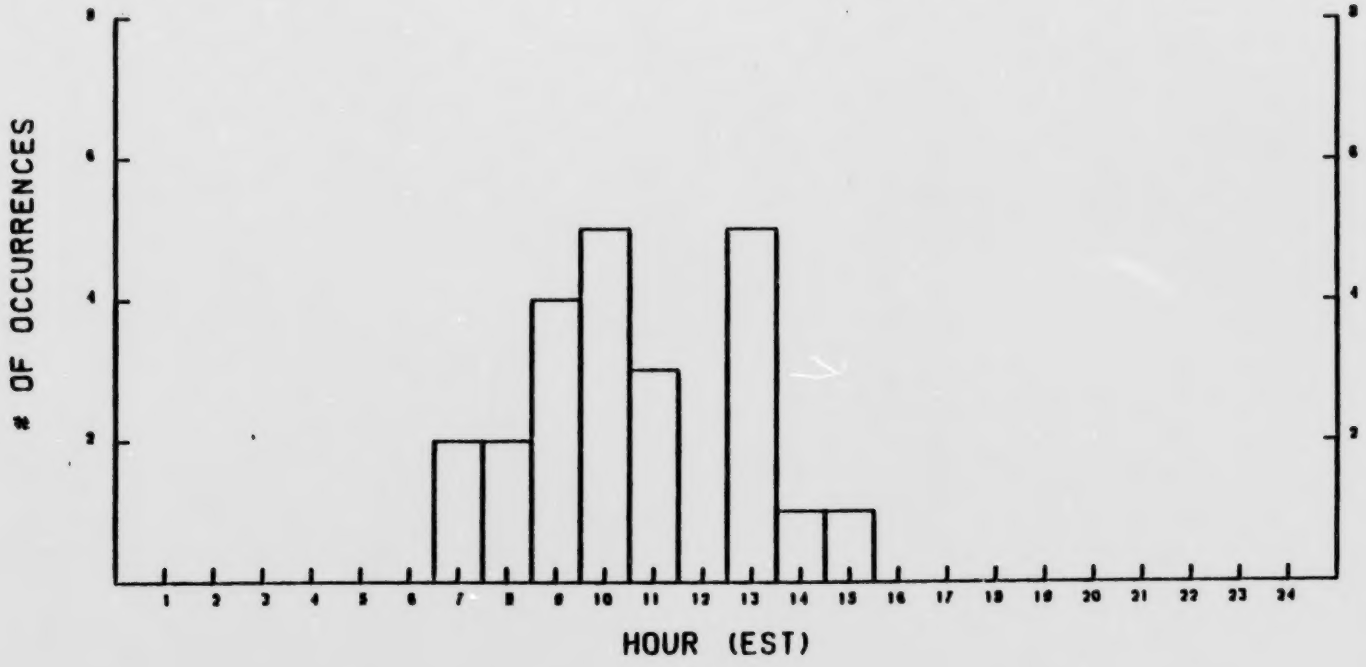
SO$_2$ Exceedance Rose (1975-1983)



* Each arm shows average SO$_2$ level for that particular direction
* The number of exceedances is shown at the end of each arm

Figure 10

Frequency Distribution of
Lake Breeze Onset Times
During Fumigation Events



APPENDIX

SYNOPTIC ANALYSIS OF SO_2 EXCEEDANCE EVENTS IN THE HALDIMAND-NORFOLK REGION - 1975 TO 1983

INTRODUCTION

In the following Appendix, meteorological conditions existing prior to and during each exceedance event are described and, where possible, an explanation as to the cause of the elevated reading(s) is given. All SO_2 concentrations are expressed in parts per billion (ppb). It should be noted also that time referred to is always eastern standard time (EST) and, for brevity, the Nanticoke G. S. station load is referred to as T.G.S. load.

Accompanying each case description is a series of plots which are defined as follows:

a) Synoptic chart closest to the hour of exceedance;
b) Diurnal variation of T.G.S. load and SO_2 concentrations for those monitors which exceeded the AQC;
c) Diurnal variation of wind speed and direction - (10 m and 85 m level of the Jarvis meteorological tower);
d) Map showing SO_2 levels throughout network during exceedance hours. Dashed line defines the wind direction (85 m level of Jarvis met. tower ± 10 degrees) during the exceedance event.
e) Diurnal variation of mixed layer heights (when available).

Event of April 22, 1975 (Figure A1)

On this morning, a high pressure system was centred over the eastern U.S. seaboard. The pressure gradient in the Nanticoke area was weak and remained so for the entire day. Winds were light and from the south. Due to unavailable temperature data on April 22, 1975, lake breeze influence could not be associated with the exceedance event.

At monitor NO7, an hourly averaged SO_2 concentration of 420 ppb was recorded at 1300. Further downwind, NNE17 recorded 120 ppb for the same hour. The T.G.S. load during the exceedance hour was 1300 MW.

Event of May 25, 1975 (Figure A2)

Throughout the morning period, the controlling high pressure was a ridge extending from Massachusetts to eastern James Bay. Surface winds at Nanticoke were from the south averaging 18 km/hr. At the time of exceedance, a warm front was located over the Nanticoke area. The frontal surface may have had an influence on the SO_2 diffusion.

At monitor NNE17, the SO_2 levels exceeded 100 ppb from 1100 to 1600, reaching a maximum value of 310 ppb at 1500.

Event of July 16, 1975 (Figure A3)

The Nanticoke area lay under the influence of a weak pressure gradient. During the early morning hours the winds were calm. As the morning progressed, the flow became light and from the southerly sector. By midnight calm conditions returned to the Nanticoke area. A lake breeze influence was associated with the high southerly winds on this day. The lake/land temperature difference was 7°C and the skies were clear. The lake breeze began at 0900 and persisted throughout the afternoon into the early evening.

An hourly averaged concentration of 300 ppb SO_2 was recorded at NNE 16 at 1500. The T.G.S. load at the time of exceedance (1500) was 1100 MW. It had increased 400 MW during the two-hour period prior to the exceedance hour.

Event of July 18, 1975 (Figure A4)

The synoptic pattern on this day was much the same as on July 16, 1975 except that the pressure gradient was stronger over the Nanticoke area. Because of the pressure gradient and the smaller land/lake temperature difference (3°C), there was no lake breeze development on July 18. The Nanticoke area was influenced by a southwesterly gradient flow of maritime tropical air.

Two exceedances of the provincial AQC occurred at 1400. NNE09 and NNE15 recorded readings of 330 ppb SO_2. T.G.S. load was fairly constant at 1300 MW prior to and during the exceedance hour.

Event of August 2, 1975 (Figure A5)

At 0700 a high pressure system was centred off the coast of South Carolina. A low pressure centre was moving slowly eastward across Northern Ontario lying just west of James Bay at 1300. The surface gradient near Lake Erie was very weak. Wind flow at Nanticoke was light and variable throughout the early morning hours. The onset of a lake breeze was apparent at 1000 and persisted throughout the afternoon period. By 1900, the lake breeze broke down and calm conditions returned.

SO_2 readings at NNE16 rose sharply to 260 ppb at 1300. A light south-southwesterly wind persisted during the exceedance hour. The T.G.S. load ranged from 1000 MW at 1000 to 1400 MW at 1300.

Event of October 27, 1975 (Figure A6)

Nanticoke was situated in the midst of a weak pressure gradient. Winds at the time of the exceedance were very light and from the south southwest. A high pressure system was located over the northern Atlantic seaboard for the entire day. At NE10, the SO_2 levels exceeded the provincial AQC at 1300. During the same hour, 70 ppb was recorded at NNE16 and 140 ppb was recorded at NNE09. The T.G.S. load increased sharply from 1300 MW in the morning period (0800) to 2000 MW by early afternoon.

Event of November 1, 1975 (Figure A7)

A high pressure ridge extended along the Atlantic coast and a low pressure system was located over James Bay. The pressure gradient between the low and high was very steep, creating a strong (38 km/hr) southwesterly wind at Nanticoke. The AQC was exceeded for three consecutive hours (0600, 0700 and 0800) at NNE09. NNE16 recorded a value of 340 ppb at 0600 and remained above 100 ppb for the next two hours. High winds inhibited plume rise which led to the exceedance event. The T.G.S. load increased from 1500 to 1900 MW during the three-hour period.

Event of January 19, 1976 (Figure A8)

On this day, the winds were in excess of 30 km/hr from the south-southwest. A high pressure system to the east of Nanticoke was responsible for the strong southerly flow. Exceedances were recorded at both NNE09 and NNE16. Winds gusting to 40 km/hr the previous hour may have been the cause of this exceedance.

Event of January 28 and 29, 1976 (Figure A9)

A low pressure system positioned over the upper Great Lakes caused the winds at Nanticoke to be southwesterly. Wind speeds were gusting over 40 km/hr. The AQC was exceeded at 2300 on January 28 at NNE09 and again at 0100 on January 29 at NE10. T.G.S. load remained fairly constant at 2000 MW throughout the day. High wind fumigation caused elevated glc's on January 28 and 29.

Event of June 18, 1976 (Figure A10)

At 0800, a low pressure system was centred just north of Lake Superior. Winds at Nanticoke were easterly. By 1400, the low had moved to the north and strengthened the pressure gradient in the Nanticoke area. Winds were 18 to 20 km/hr and were from the south. At 1100, the SO_2 monitor at NNE16 recorded a concentration of 280 ppb. By noon, the level had reached 430 ppb. A second monitor, NO7, recorded an exceedance (310 ppb) at 1500. During the entire period, the Nanticoke T.G.S. was operating at a constant load (1300 MW). High SO_2 levels on this day cannot be explained from the available information.

Event of June 22, 1976 (Figure A11)

At 0800, the Nanticoke area was under the influence of a weak pressure gradient. A high pressure system was centred over the eastern Atlantic. By 1400, the land/lake temperature difference reached 8°C under clear skies and a lake breeze was established. A fumigation of SO_2 was recorded for two consecutive hours at NO7. During the fumigation event, the T.G.S. load was constant at 1300 MW. The decrease in SO_2 levels at 1700 coincided with the breakdown of the lake breeze.

Event of July 9, 1976 (Figure A12)

The Nanticoke area was under the influence of a high pressure system centred over Sarnia. Initially the winds were light and from the north. However, by 1400 the winds had shifted to the south. The pressure gradient established by the lake/land temperature difference (3°C) was responsible for the development of a weak lake breeze which began at 1400 and had dissipated by 1900. The monitor at NNW15 recorded an SO_2 concentration of 300 ppb at 1700. The wind was from the south-southeast at 16 km/hr and the T.G.S. load was constant (1300 MW) around the time of exceedance. The fumigation of SO_2 occurred during the lake breeze influence.

Event of July 28, 1976 (Figure A13)

On this day, a warm front moved slowly northeastward but remained southwest of Nanticoke until after the fumigation. A low pressure system was located over the upper St. Lawrence. Nanticoke was under the influence of a weak pressure gradient. Winds at the Jarvis meteorological tower were off-shore during the early morning hours, becoming easterly aroung 0900 and finally turning on-shore for three hours (1300, 1400 and 1500). The brief afternoon on-shore flow was due to the formation of a weak lake breeze. Later in the afternoon the wind direction returned to northeasterly.

This fumigation event produced two hourly exceedances at one station and another exceedance at a nearby monitor. WNW20 recorded 650 ppb at noon and still showed 320 ppb by 1300. A second station NNW08 had SO_2 readings of 370 ppb at 1500. Other monitors (NNW15, NNW11 and NO8) reported SO_2 levels over 100 ppb during the same period. The T.G.S. load was constant at 1500 MW throughout the pollution event. The SO_2 fumigation occurred simultaneously with the on-shore flow generated by the lake breeze.

Event of August 14, 1976 (Figure A14)

Throughout the early morning hours on August 14, a quasi-stationary front was located just south of the lower Great Lakes. By 1400, the wind flow in the Nanticoke area shifted to the southerly quadrant in response to frontal disturbance throughout the Nanticoke region.

An exceedance of the AQC was recorded by NNW11 (280 ppb) at 1600. SO_2 concentrations of 60 ppb and 210 ppb were also recorded at NNW08 and NNW15 respectively. T.G.S. load was constant at 1400 MW.

This fumigation event was caused by frontal activity.

Event of August 19, 1976 (Figure A15)

At 0800, the Nanticoke area was in the midst of a weak pressure gradient with a high pressure system centred to the east of Lake Erie. Winds were calm from 0600 to 1200. By 1300, a maximum temperature difference (4°C) between the land and lake was established, generating a lake breeze. With south-southeasterly winds (11 km/hr), the SO_2 monitor at NNW15 recorded an exceedance (310 ppb) at 1600. By 1800, the lake breeze dissipated and the SO_2 levels decreased.

Event of October 11, 1976 (Figure A16)

Meterological conditions on this day were influenced by a high pressure system centred over the lower Great Lakes. As the day progressed, the surface winds in the Nanticoke area turned from easterly at 0700 to southerly by 1300. Movement of the high pressure cell coincided with the shift in wind direction. Because the lake was warmer than the land on this day, the lake breeze regime did not develop. Synoptic southerly flow coupled with strong solar radiation, however, may have produced the TIBL which could have led to the elevated glc's.

Two consecutive hourly exceedances occurred at NNW08. SO_2 concentrations of 280 ppb and 290 ppb were recorded at 1400 and 1500 respectively.

Event of October 15, 1976 (Figure A17)

A low pressure system situated over the Great Lakes produced a south-southwesterly flow in the Nanticoke area. Two exceedances occurred at 0200; one was recorded at NNE09 (270 ppb) and the other at NNE16 (290 ppb). At 0400, the monitor at NNE09 recorded a second exceedance (260 ppb) while the SO_2 level at NNE16 decreased to 160 ppb. The exceedances coincided with a drop in load from 1000 to 500 MW. High winds (25 km/hr) caused the plume to impinge at ground level during the early morning hours.

Event of March 21, 1977 (Figure A18)

The Nanticoke region was under the influence of a low pressure system in the Ohio Valley and a high pressure ridge extending from James Bay to Pennsylvania. Surface winds at Nanticoke were southerly. By 2000, the low pressure system moved through the lower Great Lakes region, causing a shift in wind direction. Surface winds were now from the northeast. The shift in wind direction coincided with an elevated SO_2 concentration (250 ppb) at NNE16. The T.G.S. load had been constant at 1500 MW for most of the day.

This is one of the few cases in which the monitor recording the elevated SO_2 value was not downwind of the T.G.S. Most probably, the elevated reading was due to the plume being caught in the frontal surface.

Event of May 22, 1977 (Figure A19)

A high pressure system was centred to the east of Nanticoke and a low was located west of Lake Superior. By 1400, the low had moved northward with the high pressure system remaining stationary. The Nanticoke area remained in a southwesterly flow of maritime tropical air throughout the day. Skies were clear and surface air temperatures reached 29°C. It is possible that the strong southwesterly winds were a combination of large scale and lake influence. The AQC was exceeded at 1500. The SO_2 monitor at NNE17 recorded a concentration fo 370 ppb. The station load at Nanticoke was 1900 MW.

Event of May 24, 1977 (Figure A20)

Quasi-stationary high pressure system located off the Atlantic coast caused the southerly flow in the Nanticoke area on May 24, 1977. Thunderstorm activity in the afternoon explains the variability in surface wind direction for the period (1400 to 2000). Unstable conditions associated with thunderstorm activity coincided with elevated SO_2 levels on this day. SO_2 fumigation occurred at NNE17 (270 ppb) at 1400.

Event of June 23, 1977 (Figure A21)

The Nanticoke area was under the influence of a weak pressure gradient. A high pressure system was centred over Lake Ontario. Throughout the night the winds were very light from the east-northeast to east. Skies were clear and the land/lake temperature difference was 5°C. At 0900, the onset of a lake breeze was evident.

Winds were southeasterly at 10-13 km/hr. All three monitors located NNW of the T.G.S. reported SO_2 levels exceeding the AQC. NNW11 recorded 300 ppb at 1300, NNW08 recorded 590 ppb at 1400 and NNW15 recorded 250 ppb at 1500. During the period of exceedances, the T.G.S. load dropped from 2000 to 1700 MW. Fumigation of SO_2 coincided with the lake breeze influence.

Event of August 26, 1977 (Figure A22)

On this day, a large high pressure system was centred over the eastern seaboard and a strong low was located to the northwest of James Bay. The surface winds at Nanticoke were southeasterly to south southeasterly for most of the day. The land/lake temperature difference reached a maximum of 2°C and the skies were cloudy. The moderate southeasterly winds were associated with the large scale gradient flow.

An SO_2 exceedance (270 ppb) was recorded by NNW08 at 1300. During the hour preceding the exceedance, the T.G.S. load decreased from 1000 to 600 MW.

Event of August 31, 1977 (Figure A23)

During the afternoon of August 31, a warm front moved through the Nanticoke area. The surface winds shifted from southeast to southwest during the later morning period. Visibility throughout the day was restricted to 6 km. At NNE17, SO_2 levels reached 330 ppb at 1300, then dropped to 22 ppb by 1400.

T.G.S. load throughout the day was constant at 1000 MW. The fumigation of SO_2 coincided with the passage of the warm front.

Event of December 23, 1977 (Figure A24)

On December 23, a deep low was centred just north of the upper Great Lakes. A steep pressure gradient over the Nanticoke area produced strong southwesterly winds. The SO_2 monitor NNE09 recorded three hourly exceedances; the first of which occurred at 0500 (270 ppb); the second at 0600 EST (290 ppb) and the third at 1100 (260 ppb). The high SO_2 levels coincided with a rapid increase in load (800 MW at 0500 to 2500 MW at 0900). High wind fumigation caused the elevated SO_2 levels on December 23, 1977.

Event of January 26, 1978 (Figure A25)

At 1900, an intense low was centred over Lake Huron, producing a strong pressure gradient across the Nanticoke area. Surface winds in excess of 90 km/hr from the southwest were recorded at the Jarvis meteorological tower.

An SO_2 exceedance occurred at NNE09. A concentration of 310 ppb was recorded at 1900. The T.G.S. load was 1200 MW during the period of exceedance. High winds caused the plume to impinge on the ground on this day.

Event of April 19, 1978 (Figure A26)

On this day, a low was centred south of Windsor at 0800. Winds in the Nanticoke area were responding to the pressure gradient. As the low approached the Lake Erie region, the surface winds shifted from east to south-southeast. Two exceedances of the AQC were recorded (at the same monitor location) during the morning of April 19. At 1000, NNW08 recorded an SO_2

concentration of 280 ppb and at 1100 the concentration was 260 ppb. The T.G.S. load was 1700 MW during the exceedance period. By late afternoon, the low had passed through the Nanticoke area causing the winds to shift from east-southeasterly to northeasterly. Instability associated with a low pressure system produced turbulent eddies which brought the plume to the ground.

Event of May 18, 1978 (Figure A27)

The Nanticoke area was under the influence of a very weak pressure gradient throughout the day. A weak high pressure system was situated west of Lake Michigan. Surface winds at Nanticoke were off-shore during the early morning hours (0100 to 0500) and became calm by 1000. By early afternoon, light south-southwesterly winds were established under the influence of a lake breeze regime. Onset time of the lake breeze was 1100 and it persisted for six to seven hours. The lake/land temperature difference was 5°C. At 1300, the SO_2 monitor at NNE09 recorded an AQC hourly exceedance. Other monitors downwind recorded higher than normal SO_2 levels for this hour (NNE17-70 ppb; WNW03-100 ppb; NO7-90 ppb and E05-140 ppb). The increase in SO_2 levels coincided with the onset of the south-southwesterly wind component.

Event of June 1, 1978 (Figure A28)

At 0800 on June 1, a high pressure area was centred over southern James Bay and a low pressure was centred west of Lake Superior. A front lay just south of the Nanticoke area in a northeast-southwest direction. By 1400, the front had moved to the north of Lake Erie and surface winds switched to a southerly direction.

Monitoring station NNE16 recorded an SO_2 exceedance (360 ppb) at 1500. High SO_2 levels coincided with the passage of the warm front.

Event of June 6, 1978 (Figure A29)

During the early morning hours of June 6, the Nanticoke area was under the influence of a very weak pressure gradient. The surface winds were calm. By 1400, a low pressure system previously centred over southern James Bay moved eastward, producing a moderate southerly flow over the Nanticoke area which persisted well into June 7. An exceedance was recorded at NNE09 for two consecutive hours. At 1500, the concentration was 350 ppb and increased to 710 ppb at 1600. NNE16 recorded 80 and 210 ppb for the same two hours.

The T.G.S. load increased from 900 MW at noon to 1300 MW by the time of the exceedance.

Event of June 23, 1978 (Figure A30)

A very weak pressure gradient persisted over the Nanticoke area on June 23. Light northeasterly winds were blowing off-shore till noon. After noon, the surface winds changed to a southerly direction. The directional change was due to a lake breeze regime as there was no large scale influence evident on the surface synoptic charts to cause such an abrupt change. The late onset time of the lake breeze could be due to a small land/lake temperature differential (only 3°C). During the on-shore flow, station NNE10 recorded hourly AQC exceedances at 1500 (390 ppb) and at 1600 (300 ppb).

Event of July 7, 1978 (Figure A31)

A low pressure system was centred to the west of Lake Michigan and the centre of the high pressure was located just east of New York. Winds were light in the early morning but increased throughout the day. The wind direction remained southerly. The increase in 10 m level winds was most likely due to the erosion of the surface inversion and recoupling of the surface with the gradient flow. Surface air temperatures were 30°C on this day. While it is possible that a lake breeze was masked in the gradient flow, the strength of the gradient flow (as shown by the strong winds at the 85 m level of the Jarvis tower) makes it unlikely that a true lake breeze developed.

The monitor at NNE16 recorded an SO_2 exceedance (270 ppb) at 1400. NNE10 and NNE09 recorded higher than background levels during the same hour (40 ppb at NNE10 and 70 ppb at NNE09).

Event of July 17, 1978 (Figure A32)

Throughout the day, the Nanticoke area was under the influence of a high pressure system. Winds were light and from the northerly direction until 1400. By 1500, the winds (85m level of the Jarvis met. tower) shifted to the southerly quadrant, the shift in direction likely due to a lake breeze regime. By 2200, the winds returned to a northerly direction coinciding with the apparent breakdown of the lake breeze. The lake/land temperature difference on July 17 was 5°C and skies were clear. The AQC was exceeded at 1700 on

July 17. NNE10 recorded an SO_2 concentration of 310 ppb. Elevated SO_2 levels coincided with lake breeze influence.

Event of August 1, 1978 (Figure A33)

A deep low centred over Hudson Bay influenced the meteorological conditions in the Nanticoke area on August. A stationary front situated to the northwest of Nanticoke on August 1 moved southeast and finally passed through the Lake Erie region at 0200 on August 2. A moderate gradient wind from the south prevailed at Nanticoke for the entire day.

At 1400 on August 1, NNE10 recorded 280 ppb. The T.G.S. load was under 1000 MW during the exceedance.

Event of August 2, 1978 (Figure A34)

Meteorological conditions on August 2 were similar to those on August 1. A low pressure system to the nothwest and a high presure cell to the east caused a moderate (20-30 km/hr) flow around Nanticoke. At 1600 on August 2, station NNE10 recorded 320 ppb of SO_2.

Event of August 15, 1978 (Figure A35)

Synoptic conditions on this day were very similar to those on August 1 and 2. A low pressure cell was centred over lower Hudson Bay. A weak warm front passed through the Nanticoke area during the mid-afternoon. Heavy cloud and thunderstorms associated with the front moved through the Nanticoke area. Wind direction remained southerly for the entire day. At 1400, NNE10 recorded an AQC exceedance (260 ppb). Elevated SO_2 levels coincided with frontal activity.

Event of September 1, 1978 (Figure A36)

At 0800, the Nanticoke area was under the influence of a weak pressure gradient. A high pressure system was situated to the south of Lake Erie. Light northwesterly winds prevailed over the area. As the morning progressed, the winds became calm. By 1400, a high pressure cell had moved over Lake Erie and the winds at the Jarvis meteorological tower became south to south-

southwesterly for the afternoon period, gradually shifting to westerly by late evening.

The light southerly winds during the afternoon period were due to lake breeze influence. Surface land temperatures did not exceed those of the lake until late morning. By 1300, the lake/land temperature difference was 3°C. The pressure gradient created by the land/lake temperature difference (due to the absence of the large scale influence) caused the weak southerly flow.

At 1700 on September 1, 260 ppb SO_2 was recorded at NO7. Other monitors downwind in the network were recording above background levels of SO_2 at this same hour (i.e. WNW03-100 ppb; NNW08-80 ppb; N15-60 ppb; NNE20-50 ppb; and NNE10-90 ppb).

Event of September 19, 1978 (Figure A37)

On September 19, Nanticoke was centred between two high pressure cells. One high pressure cell was located to the south of the Great Lakes and a second high was centred over southern Quebec. A quasi-stationary front was oriented in a WNW-ESE direction just south of Lake Erie. Although winds were light from the northeast for most of the day, there was also a calm period (1800 to 2100). It was during this period that relatively high SO_2 concentrations (260 ppb) were recorded at W13. The AQC was exceeded at 2000.

Event of September 27, 1978 (Figure A38)

A strong high pressure system situated south of Lake Erie moved slowly in a northeast direction on the morning of September 27. The moderate southerly winds at Nanticoke were associated with the backside of this high pressure system. NNE09 recorded 270 ppb at 1100. At this time, the winds were south southwest at 34 km/hr. T.G.S. was operating at constant load (1300 MW). High wind fumigation produced the elevated SO_2 levels on September 27, 1978.

Event of October 30, 1978 (Figure A39)

A high pressure system was situated over the eastern Atlantic coast and a deep low was located over southern James Bay. Nanticoke was under the influence of a moderate pressure gradient. Moderate southerly winds at noon coincided with a high SO_2 concentration (390 ppb at NO7). SO_2 levels at NO7 remained above 100 ppb for three consecutive hours (140 ppb at 1300 and 210 ppb at 1400).

Event of December 13, 1978 (Figure A40)

A low pressure system was centred over the upper Great Lakes. Winds at Nanticoke were southwest at 46 km/hr. At 0300, NNE09 recorded 350 ppb SO_2 while NNE16 recorded 180 ppb SO_2. T.G.S. load decreased from 1800 MW at 0200 to 1600 MW at 0300. High winds caused the elevated SO_2 levels on this day.

Event of April 6, 1979 (Figure A41)

An intense low pressure system was situated to the northeast of Nanticoke near Montreal. A strong pressure gradient existed over Lake Erie which produced very strong westerly winds (77 km/hr). High winds caused the plume to fumigate at E05. 250 ppb SO_2 was recorded at noon on April 6.

Event of May 2, 1979 (Figure A42)

At 0700, a high pressure ridge was centred over Lake Ontario. The Nanticoke area was in the midst of a weak pressure gradient. Winds (as measured by the Jarvis met. tower) were light and from the east. By noon, the winds had turned slowly clockwise and were now out of the southeast and remained southeast for the afternoon period. They turned back to easterly and finally to northeasterly by 1800. The southeast component during the afternoon was due to a lake breeze influence. The land/lake temperature difference was 7°C. Exceedances of the AQC occurred at NNW08 (300 ppb) and NNW11 (300 ppb) at noon.

Event of May 5, 1979 (Figure A43)

A high pressure ridge moved through the Nanticoke area on the morning of May 5. By 1300, the wind at the Jarvis met. tower shifted from northwesterly to southerly as the ridge passed through. Two hourly exceedances of the provincial AQC coincided with the southerly wind flow. The monitor at NNE10 recorded 270 ppb, 260 ppb was recorded at 1400 and 1500 respectively.

Event of July 27, 1979 (Figure A44)

On this day, a large area of high pressure centred over southern Ontario influenced the meteorological conditions. The winds for most of the day were light and variable. By 1500, a southerly component could be discerned. Prior to 1500, during calm conditions, there were five exceedances of the AQC. WNW03 recorded 560 ppb at 1100 EST; then at 1200 NNE09 recorded 400 ppb; NNE16 recorded 250 ppb and NO7 recorded 360 ppb. The last hourly exceedance was recorded by NO7 (260 ppb) at 1300. Although there was a good chance of lake breeze development on July 27, a low surface temperature kept the land/lake temperature difference to 10C. SO_2 fumigation coincided with calm conditions on July 27, 1979.

Event of January 7, 1980 (Figure A45)

Intense low pressure cell centred over the upper Great Lakes created a strong pressure gradient in the Nanticoke area. Winds were strong (66 km/hr) and from the south southwest at the time of the exceedances. NNE05 recorded 300 ppb and 270 ppb was recorded at 0500 and 0600 respectively. T.G.S. was operating at a very low load (300 MW) during the fumigation period.

The exceedances occurred only 5 km from the stack, suggesting downwash of the plume due to low load and high winds. Under a low station load, the gas exit velocity is decreased, resulting in a smaller buoyancy flux and hence a lower plume rise.

Event of June 16, 1980 (Figure A46)

At 0800, a high pressure system was located just west of Lake Michigan. Moderate winds at Nanticoke were from the north. Due to the eastward movement of the centre of high pressure, the winds at Nanticoke shifted from northwesterly to southwesterly by 1500. Coinciding with the wind shift, NNE10 recorded an hourly SO_2 concentration of 260 ppb at 1600. At 2000, the winds shifted back to off-shore (i.e. from the north) and the SO_2 levels decreased.

Event of July 14, 1980 (Figure A47)

Examination of the meteorological conditions on July 14 suggest the development of a well defined lake breeze. During the early morning hours a weak pressure gradient covered the Nanticoke area. Winds were light and variable. At 0800, the winds began to turn on-shore and by 1100 the flow was predominantly from the south.

Under clear skies, the lake/land temperature difference reached a maximum of 7°C. These conditions, coupled with a weak pressure gradient over Lake Erie, produced a flow from the lake to the land for the period (0800 to 2200), after which calm conditions prevailed for the rest of the day.

Mixed layer heights on July 14 were in the 200 m range for the entire day. However, it should be noted here that the mixed layer height are obtained from an acoustic sounder located only 5 km from the shoreline whereas the AQC exceedances occurred at a distance of 16 to 20 km from the shoreline.

At noon on the 14th, two stations recorded SO_2 fumigations. NNE16 and NNE20 recorded 410 and 310 ppb respectively. The Nanticoke T.G.S. was brought on line at 0400. The station load increased sharply and reached a maximum load (2500 MW) at 1000. The fumigation event coincided with lake breeze influence.

Event of July 18, 1980 (Figure A48)

A weak pressure gradient was located over the Nanticoke area for most of the day. The lake/land temperature difference reached 7°C on this day. The onset time of the lake breeze was later than that of July 14 because the surface air temperatures increased more slowly due to the early morning fog. By 1400, the lake breeze was well defined. Mixed layer heights increased sharply during the morning of the 18th, substantiating the lake breeze influence. After 1000, the mixed layer heights are above 1000 m. It is during this period that the monitor at N15 recorded an exceedance with an hourly SO_2 average concentration of 260 ppb under a 16 km wind from the south. It is interesting to note that the mixed layer heights dropped to 100 m at 2100, due likely to a decoupling of the elevated layer with the formation of surface inversion which may have grown to 100 m by this hour.

Event of September 30, 1980 (Figure A49)

On this day, a strong high pressure system was centred over the eastern seaboard. Surface winds (as measured by the Jarvis met. tower) in the Nanticoke area were persistent from the south. It is of interest to note that the 10 m level wind speeds were greater than those at the 85 m level during the afternoon. The lake breeze flow was probably superimposed over the gradient flow, giving slightly higher 10 m level wind speeds. SO_2 readings of 250 and 140 ppb were recorded at NNE09 and NNE16 respectively. These SO_2 levels occurred at 1300. The T.G.S. was operating at constant load (1900 MW throughout the afternoon period.

Event of November 20, 1980 (Figure A50)

On November 20, a low was centred over Lake Superior and a high pressure system over the northeastern U.S. There was a strong pressure gradient over the Nanticoke area. Winds were south-southwesterly at 30 km/hr. At 1400, the monitor at NNE16 recorded a concentration of 370 ppb. The station load at the time of exceedance decreased from a maximum 2500 MW at 1000 to 2000 MW by 1400. Possibly, the variation in station load and the relatively strong winds restricted plume rise and resulted in high glc's of SO_2 on November 20.

Event of April 10, 1981 (Figure A51)

At 1300, a high pressure centre was located over the eastern seaboard and a deep low was centred northwest of Lake Superior. Nanticoke was being influenced by a strong (26-30 km/hr) south-southwest gradient flow. High glc's of SO_2 were reported at three downwind monitoring stations in the network. NNE09 recorded 140 ppb, NNE20 reported 140 ppb and NNE16 exceeded the hourly AQC (420 ppb) at 1500. The variation in T.G.S. load was similar to the last event. At the time of exceedance a decrease in station load coincided with an increase in windspeed. Once again, low plume rise resulted in high ground level concentrations of SO_2. The height of the mixed layer on the afternoon of April 10 was 200 m, 6 km from the shoreline. Further inland (NNE16), the mixed layer height may have been higher which would cause the plume to be entrained to the ground.

Event of May 4, 1981 (Figure A52)

On the morning of May 4, Nanticoke was situated in a ridge of high pressure, wedged in between two low pressure cells, one located over Hudson Bay and the other centred over the eastern seaboard. Nanticoke area was under the influence of a weak gradient flow from the south. As the day progressed, the windspeeds increased to a maximum (14 km/hr) at 1400. The maximum land/lake temperature difference (15°C) occurred at 1400 also. By 1900, the wind speeds decreased and calm conditions returned to the Nanticoke area.

It is probable that during the afternoon, the southerly flow which cannot be distinguished from the gradient flow was enhanced by a weak lake breeze. At 1600, NNE10 recorded an SO_2 fumigation (280 ppb). At the time of exceedance, the T.G.S. load was 2000 MW. The TIBL was formed by the south wind off the lake and caused the fumigation event.

Event of May 8, 1981 (Figure A53)

On this day, a high pressure system was moving slowly across New York state towards the Atlantic coast. Nanticoke once again was under the influence of a weak pressure gradient. During the early morning hours (0200 to 0500), the flow was off-shore. At 0600, the winds began to shift clockwise and by noon the flow was light to moderate from the south. The lake breeze influence persisted until 1500 after which calm conditions (lasting for two hours) were followed by an off-shore flow. Clear skies, a lake/land temperature differential of 10°C and a weak pressure gradient over the Nanticoke area all contributed to the development of the lake breeze regime.

NNW08 recorded an exceedance of the AQC at noon (270 ppb). SO_2 levels remained high (200 ppb at 1500, 170 ppb at 1700; and 140 ppb at 1800) until the winds shifted off-shore.

Event of July 3, 1981 (Figure A54)

A high pressure system situated off the Atlantic coast produced a light gradient wind from the south throughout the day. Surface air temperature reached 26°C at 1400. Mixed layer heights were slightly above 200 m by noon and appeared to be increasing. However, due to instrument malfunction the mixed layer heights for the afternoon period were unavailable. At 1400, the monitor at NO7 recorded an SO_2 concentration of 270 ppb. The following hour the concentration at NO7 increased to 450 ppb and at the same time NNE05 recorded 240 ppb. The southerly flow from the lake produced a TIBL on this day. The plume was entrained within the mixed layer and brought to the ground.

Event of August 22, 1981 (Figure A55)

Nanticoke area was under the influence of a very weak pressure gradient. A high pressure system was centred east of Lake Erie. Surface winds were easterly during the early morning hours, turning southerly in the late morning and becoming calm by 1700. A weak lake breeze may have developed. The lake/land temperature difference was 4°C and the skies were clear. The SO_2 exceedance on this day occurred at 1300. NNE05 recorded an hourly averaged concentration of 290 ppb. The mixed layer height increased from slightly above 300 m at noon to 1000 m by 1300. The plume was entrained within the mixed layer and brought to the ground.

Event of August 26, 1981 (Figure A56)

A large high pressure system was located east of Lake Erie and moved slowly eastward toward the Atlantic seaboard throughout the day. The surface winds at Nanticoke during the morning were light and from the southeast. At 2200, the monitor at E05 recorded a high SO_2 level (260 ppb). A weak lake breeze may have developed. The lake/land temperature difference was 3°C and the pressure gradient was light. The surface wind at the time of exceedance was east southeasterly at 11 km/hr. Wind direction does not correlate with an upwind source for this event. Data from the acoustic sounder charts for this exceedance period showed a very shallow mixed layer height (20-30 m) and, therefore, stable conditions throughout the plume height region. The T.G.S. load decreased from 2700 MW at 2100 to 2300 MW by 2200. The stable atmospheric conditions and the light winds may have produced the elevated SO_2 levels on August 26.

Event of October 14, 1981 (Figure A57)

A high pressure system was east of the lower Great Lakes and a low pressure system to the west of Hudson's Bay. As a result, the Nanticoke area lay in a light to moderate southerly flow of maritime tropical air. The lake breeze influence was inhibited by the relatively low surface land temperatures (16°C) and partial cloud cover.

The pollution event began at 1100. NNE10 recorded an SO_2 concentration of 300 ppb and NNE39 (which is 39 km from the T.G.S.) recorded 220 ppb. By noon, NNE39 exceeded the AQC for the first time since the inception of the monitoring network in 1978. The mixed layer height remained low (20-50 m) until 0900. By 1000, the height increased to 300 m and remained there during the exceedance hours. The T.G.S. load was in the 2200 MW range throughout the morning and afternoon.

Event of October 20, 1981 (Figure A58)

During the morning period, an intense low pressure system moved into the upper Great Lakes region from the west. As a result, there was a strong pressure gradient in the Nanticoke area. Surface winds were from the south-southwest in excess of 40 km/hr. SO_2 concentrations were above normal for a seven-hour period at NNE09. The trend in load and SO_2 levels is very similar for the morning period. The T.G.S. load and the SO_2 level at NNE09 increase very sharply between 0500 and 1000. During this same time period, surface wind speed also increased.

At 1000, 1100 and 1300 the AQC was exceeded. NNE09 recorded 320 ppb at 1000 and 1100 while NNE10 recorded 280 ppb at 1300. High winds caused the elevated SO_2 levels on October 20, 1981.

Event of October 24, 1981 (Figure A59)

A high pressure cell moving from the mid-western U.S. across the northern U.S. to a location just east of Lake Erie influenced the weather this day. Surface winds shifted from westerly to southerly with the passage of this system. At 1400, elevated SO_2 levels were recorded by five samplers located downwind in the north-northeast sector; (NNE05-130 ppb; NNE10-280 ppb; NNE09-100 ppb; NNE16-80 ppb; and NNE20-80 ppb. The SO_2 concentrations at NNE10 remained above 50 ppb until 1800, at which time a shift in wind direction coincided with a decrease in SO_2 levels. Mixed layer heights were 350 to 400 m during the afternoon period.

Event of October 25, 1981 (Figure A60)

On this day, a high pressure system was centred over the Atlantic provinces and a deep low was located over Hudson's Bay. Surface winds in the Nanticoke area were from the south at 11 to 15 km/hr. Surface land temperatures were less than the temperature of the lake, thereby inhibiting the lake breeze influence.

Elevated SO_2 levels were recorded at NO7 for three consecutive hours (1300, 1400 and 1500). The hourly AQC was exceeded at 1400 (250 ppb). During the period of elevated SO_2 levels, the mixed layer heights were in the 400 m range. Once again, a drop in wind speed and a shift in direction coincided with a decrease in SO_2 levels.

Event of November 10, 1981 (Figure A61)

The surface synoptic chart at 0700 on this day showed a light east northeasterly flow over the Nanticoke area. By 1300, an intense low moving in an easterly direction had centred itself over James Bay. This produced a light to moderate southerly flow over the Nanticoke area. Surface land temperature (4°C) was well below the lake temperature (10°C), thereby inhibiting the development of a lake breeze.

The exceedance event began with SO_2 readings of 300 ppb and 230 ppb at NNW08 and NWW15 respectively. These readings occurred at noon. At 1400, the AQC was exceeded at N15 (300 ppb) and SO_2 levels above 100 ppb were recorded at NNE05 (160 ppb) and NNE10 (130 ppb). The T.G.S. load throughout the event was 3000 MW.

Events of November 26 and 27, 1981 (Figure A62)

A deep low pressure system moving north northeastward was located over the upper Great Lakes at 0100 on November 27. Surface winds in the Nanticoke area were very strong (50 km/hr) from the southwest to west southwest direction.

This exceedance event produced not only the highest SO_2 levels of the year but also the highest levels recorded to date in the Nanticoke area. The high readings began at midnight on the 26th, at which time NNE05 recorded 310 ppb SO_2. By 0200 on November 27, NNE09 recorded 1130 ppb of SO_2 and remained high (320 ppb) for the next hour as well. The T.G.S. load was decreasing during the pollution event (from 2900 MW at 2300 on November 26 to 1100 MW at 0300 on November 27). High wind fumigation was responsible for the elevated SO_2 readings on November 26 and 27, 1981.

Event pf February 10, 1982 (Figure A63)

A high pressure system moving along a west to east axis just south of the Nanticoke area was the controlling weather factor on this day. Surface winds during the early morning hours were westerly becoming west-southwesterly by 0900.

At noon on February 10, the monitor at NE19 recorded 436 ppb. T.G.S load throughout the daytime period was constant at 3900 MW. Convective turbulence (due to the transfer of heat from the warm air to the cold land surface) may have produced the high SO_2 level on this day.

Event of July 14, 1982 (Figure A64)

At 0800, the Nanticoke area was under the influence of a weak pressure gradient. By 1400, the lake/land temperature difference reached 6°C and a lake breeze was established. From the surface synoptic map, the surface winds north of Lake Erie were southerly while the winds south of Lake Erie were northerly. The lake breeze persisted until 1700 after which calm conditions remained for the rest of the day. Mixed layer heights were above 300 m by 1500. At (1600) the monitors at NNE10, NNE16 and NNE 20 recorded concentrations above the exceedance criterion (270 ppb at NNE10, 352 ppb at NNE16 and 280 ppb at NNE20). The following hour (1700) concentrations remained above the AQC at NNE16 (417 ppb) and NNE20 (300 ppb).

The plume was entrained within the mixed layer and brought to the ground.

Event of July 16, 1982 (Figure A65)

A very weak pressure gradient persisted over the Nanticoke area on July 16. The land/lake temperature difference reached 9°C. Calm conditions lasted throughout the night and into the morning period. By 1000 a light southerly flow could be discerned. Surface winds on the south side of Lake Erie were from the north. The southerly component in the Nanticoke area was due to lake breeze influence. Suprisingly, the mixed layer heights were below 200 m for the entire day. However, as mentioned in previous events, the mixed layer heights are recorded at a site 7 km from the shoreline while the exceedance on this day occurred 20 km from the shoreline.

The monitor at NNE20 recorded an SO_2 exceedance (270 ppb) at 1500. T.G.S. load remained constant (2900 MW) throughout the entire day.

Event of September 17, 1982 (Figure A66)

The Nanticoke area was under the influence of a very weak high pressure system. Surface winds during the morning and afternoon were southerly at 8-15 km/hr. The mixed layer height increased from 300 m at 1000 to 400 m by 1500.

At 1600, the monitor at NNE09 recorded a SO_2 concentration of 273 ppb. Elevated levels were also recorded at NNE10 (120 ppb), NNE20 (109 ppb), and NNE39 (133 ppb). The plume was entrained within the mixed layer and brought to the ground.

Event of September 30, 1982 (Figure A67)

A high pressure system located to the east of Nanticoke produced a weak pressure gradient over the area. Skies were clear and the lake/land temperature difference was 5°C. A lake breeze was established by 1000 and persisted until 2000. The mixed layer height decreased from 1000 m (two hours prior to the exceedance event) to slightly above 200 m (at the time of exceedance).

The SO_2 exceedance on this day occurred at 1400. NNE16 reported an hourly averaged concentration of 256 ppb.

Event of November 11, 1982 (Figure A68)

The surface synoptic map (closest to the exceedance event) on this day showed an intense low pressure cell approaching from the mid western U.S. Surface winds in the Nanticoke area were strong (43 km/hr) from the south-southwest. Mixed layer heights were in excess of 1000 m.

The monitor at NNE05 recorded an hourly average SO_2 concentration of 280 ppb at midnight. The previous hour the SO_2 level was also high (230 ppb). During this two hour period the T.G.S. load had decreased sharply from 2200 MW at 2200 to 1200 MW at 2400. The combination of high winds and reduced T.G.S. load caused plume impingment at midnight on November 11.

Event of April 29, 1983 (Figure A69)

On this day, a high pressure system was located to the southeast of Nanticoke over the eastern U.S. seaboard. The Nanticoke area lay under the influence of a weak pressure gradient. As the morning progressed the westerly flow was replaced by a light southerly flow and by early evening the flow was out of the northeast. The lake/land temperature difference was 8°C. A lake breeze was established on this day and it coincided with the elevated SO_2 readings. The mixed layer height increased from 50m at 0700 to 500 m by 0800.

SO_2 exceedances were recorded at station NNW08 for two consecutive hours. At 1200 and 1300 the concentrations were 252 and 262 ppb respectively. During the same two hour period the monitors at NNW15 and N15 also recorded concentrations in excess of 100 ppb. The T.G.S. load was 3000 MW and the mixed layer height was 400 to 500 m during the exceedance hours. The plume was entrained within the mixed layer and brought to the ground.

Event of May 13, 1983 (Figure A70)

A high pressure cell situated directly north of Nanticoke produced an easterly flow over the area. An exceedance of the provincial criterion was recorded by W13 (251 ppb) at noon. Mixed layer heights were in the 300 to 400 m range. The T.G.S. load increased from 800 MW at 0500 to 3000 MW by 0700 and remained there during the exceedance hour.

Event of June 22, 1983 (Figure A71)

Examination of the meteorological conditions on June 22, suggests the development of a well defined lake breeze. During the early morning hours a weak pressure gradient covered the Nanticoke area. Winds were calm. By noon, the flow was from the lake to the land. The onset time of the lake breeze was 1100. The land/lake temperature difference was 9°C.

At 1100 and 1200, the monitor at NNW08 recorded concentrations of 438 and 411 ppb respectively. The increase in SO_2 levels coincided with the onset of the south-southeasterly wind component.

Event of August 14, 1983 (Figure A72)

Nanticoke was under the influence of a very weak pressure gradient. A high pressure system was centred to the east of Buffalo. Surface winds were calm until noon, at which time a light gradient flow from the south became apparent and persisted through the afternoon. Mixed layer heights were in the 350 to 400 m range during the afternoon.

At 1500, the monitor at NNW08 recorded an SO_2 exceedance (313 ppb). The T.G.S. load was 1400 MW throughout the exceedance hour.

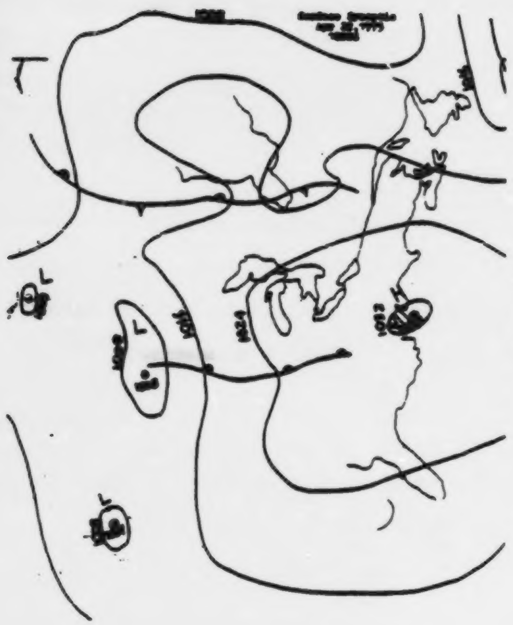
Event of August 17, 1983 (Figure A73)

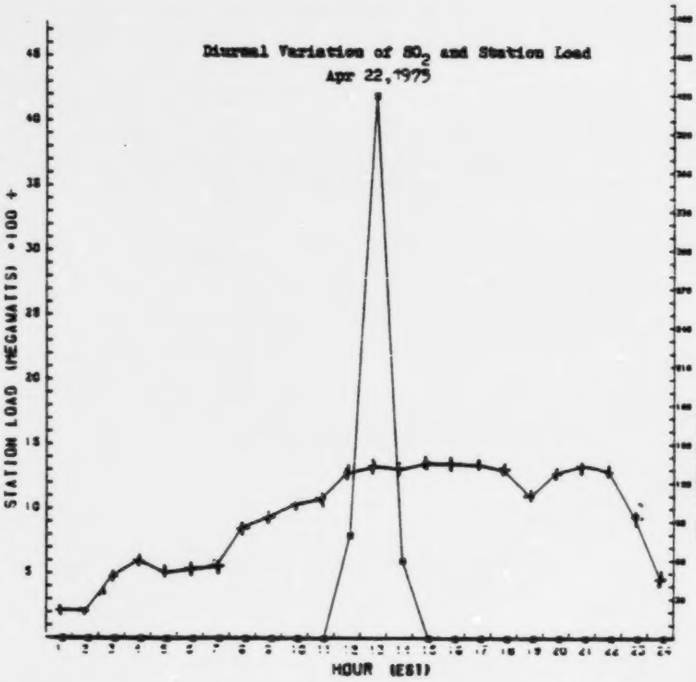
On this day the Nanticoke area was under the influence of a weak low pressure disturbance which was moving in a northeasterly direction. The surface flow was moderate (15 to 20 km/hr) from the south-southwest. Meteorological conditions were hot, hazy and humid. Throughout the afternoon, the mixed layer heights ranged from 300 to 400 m.

The monitor at NNE 20 recorded an SO_2 exceedance (291 ppb) at 1300. Elevated SO_2 was also recorded at NNE16 (221 ppb); NNE09 (89 ppb) and NNE10 (40 ppb). The T.G.S. load was constant at 3500 MW during the afternoon.

Event of September 21,1983 (Figure A74)

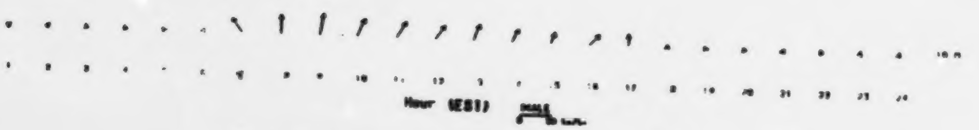
The controlling meteorological condition around the time of elevated SO_2 was a low pressure cell centred over James Bay. Surface winds at the time of exceedance were strong (35 km/hr) from the south-southwest. The mixed layer height was 300 m during the exceedance hour. NNE05 recorded a concentration of 320 ppb at 0200. The T.G.S. load was only 1200 MW. The combination of low load and high winds caused the elevated SO_2 on this day.



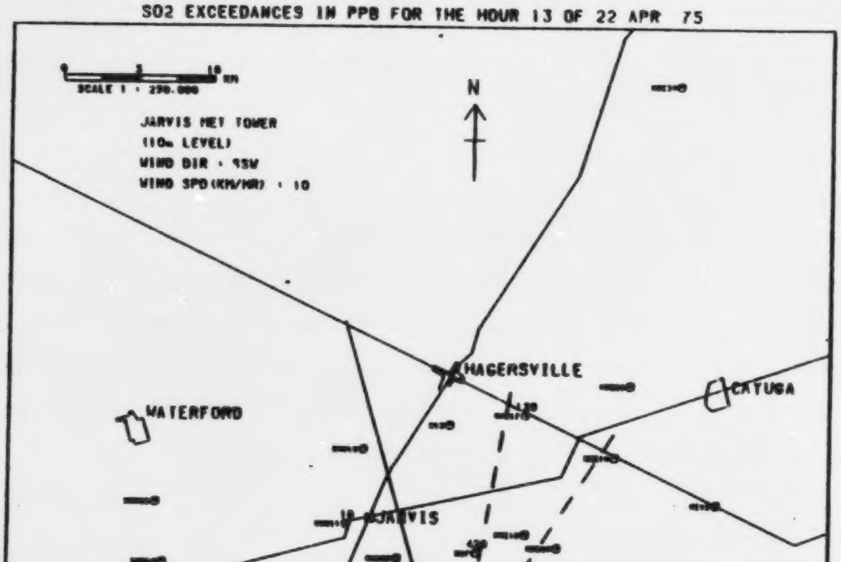


Wind speed and direction at EHE11

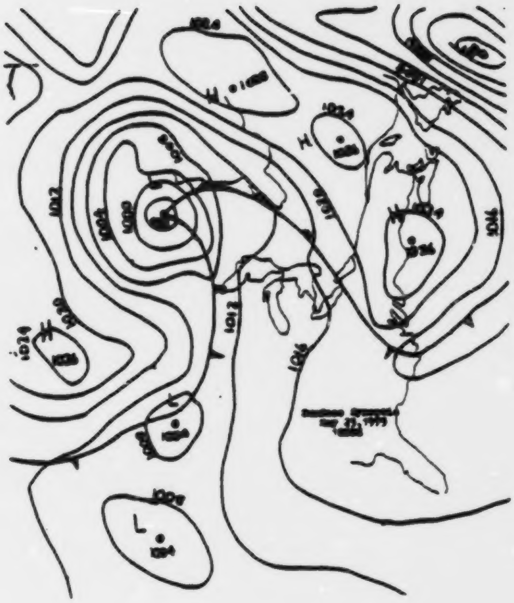
22 APR 1975

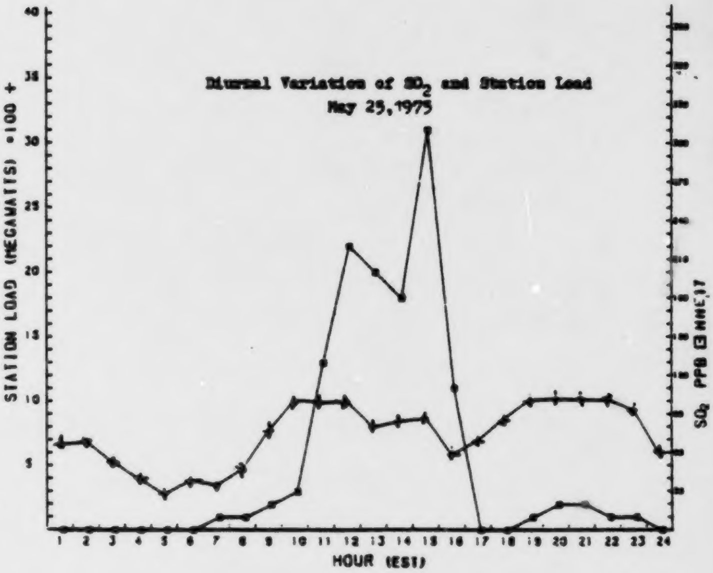


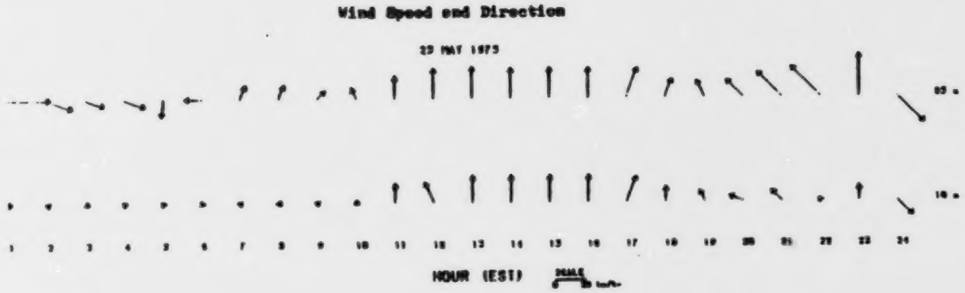
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 22 APR 75



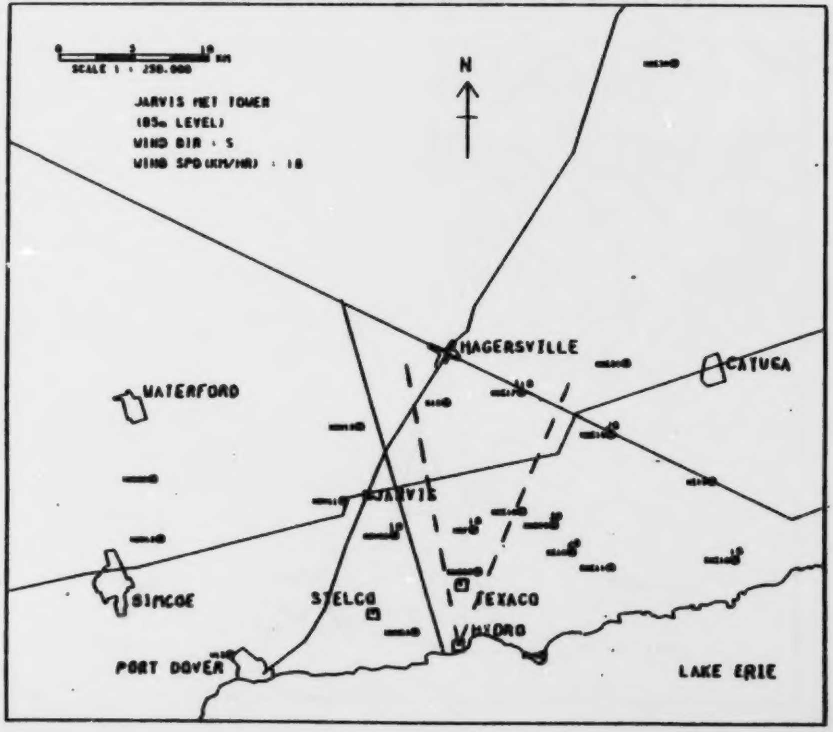
SO$_2$ EPISODE OF MAY 25,1975



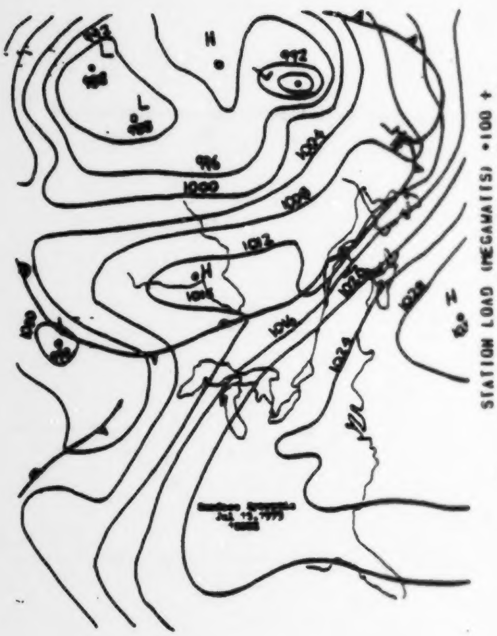


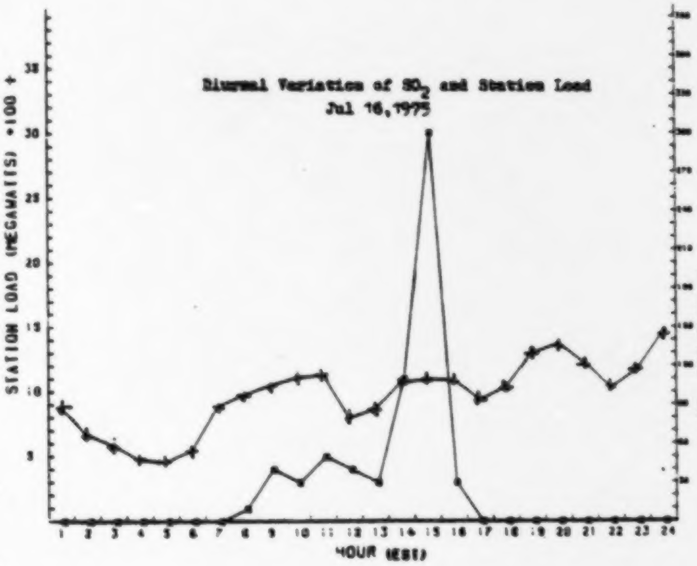


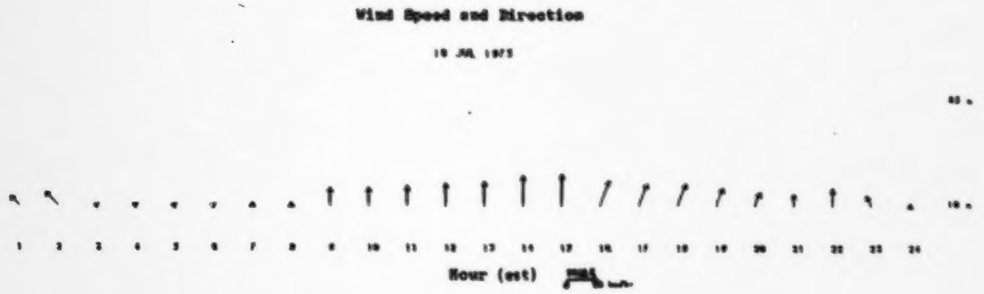
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 25 MAY 75



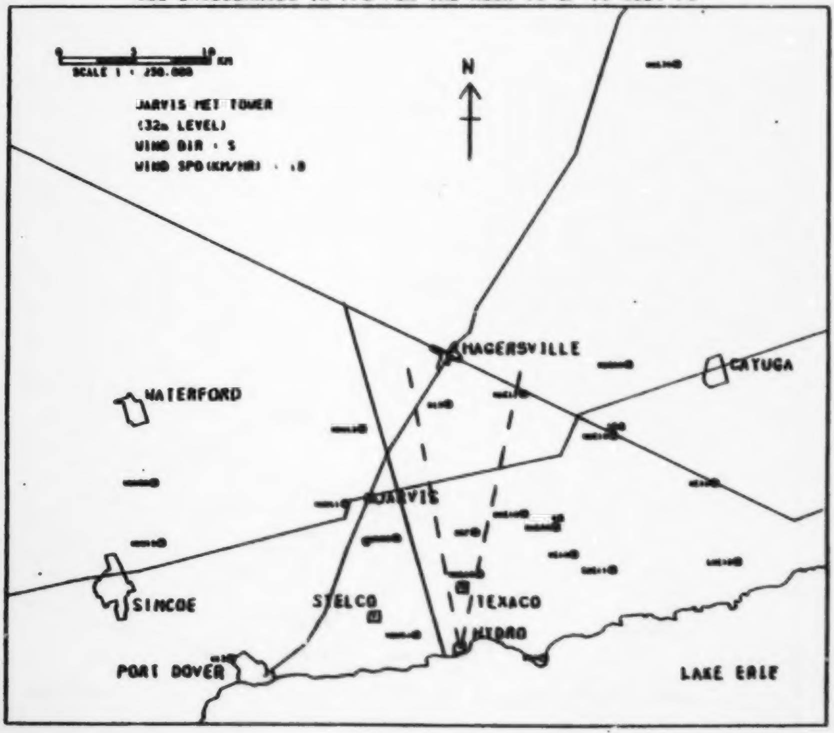
SO_2 EPISODE OF JULY 16,1975



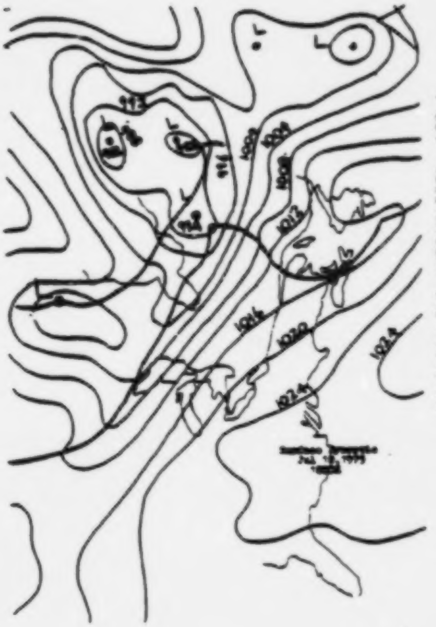


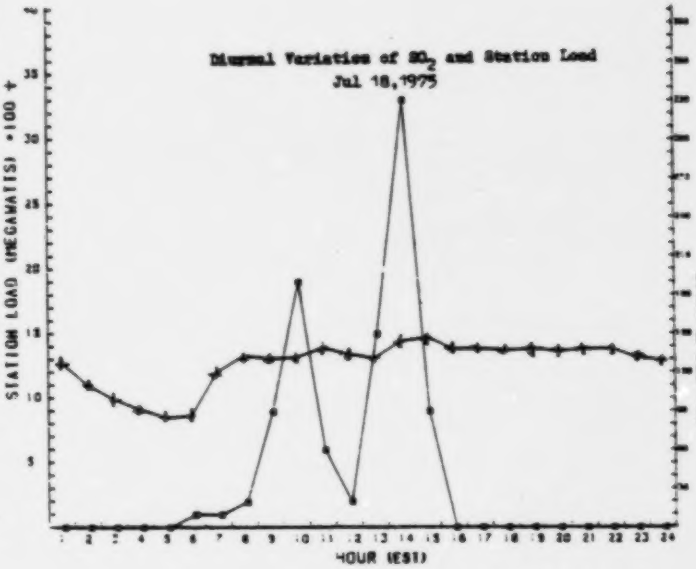


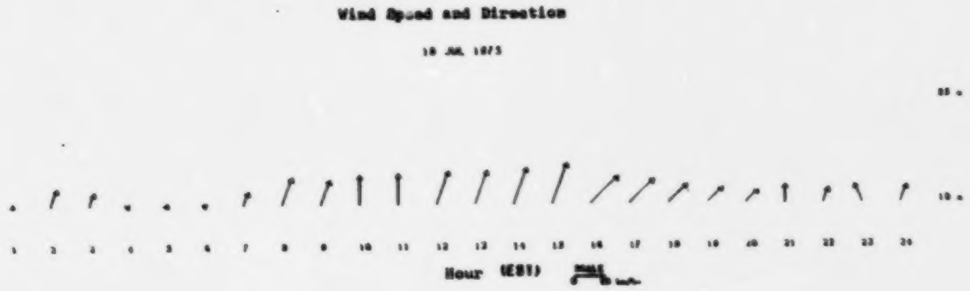
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 16 JULY 75



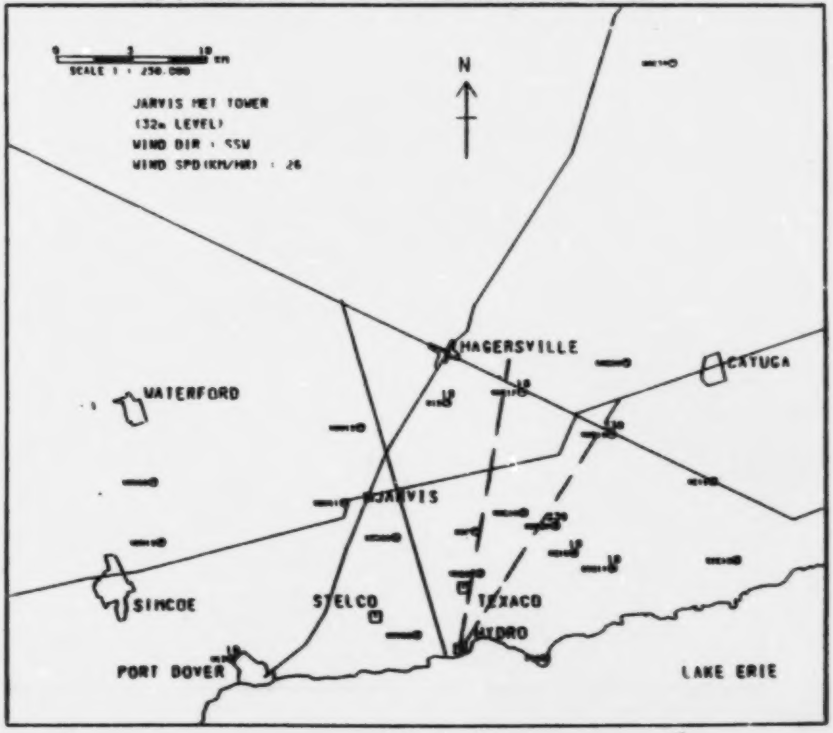
SO$_2$ EPISODE OF JULY 18,1975

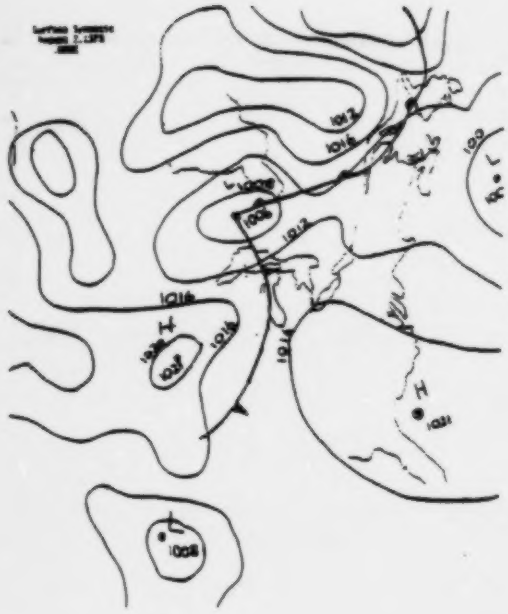


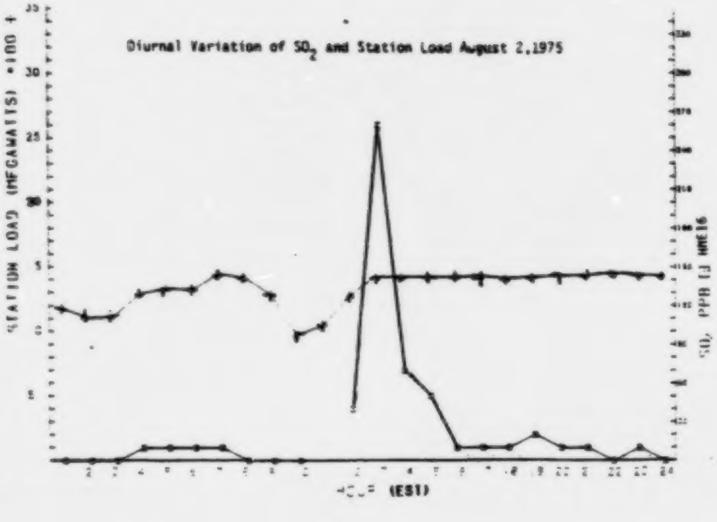


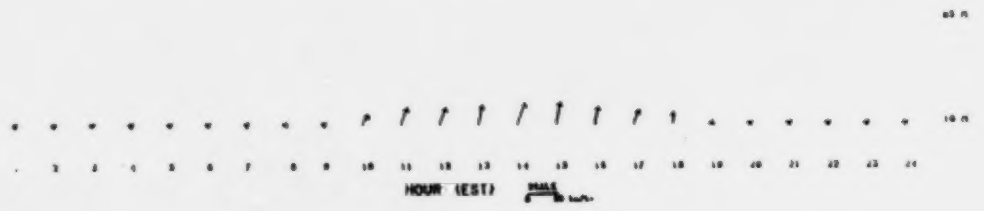


SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 18 JULY 75



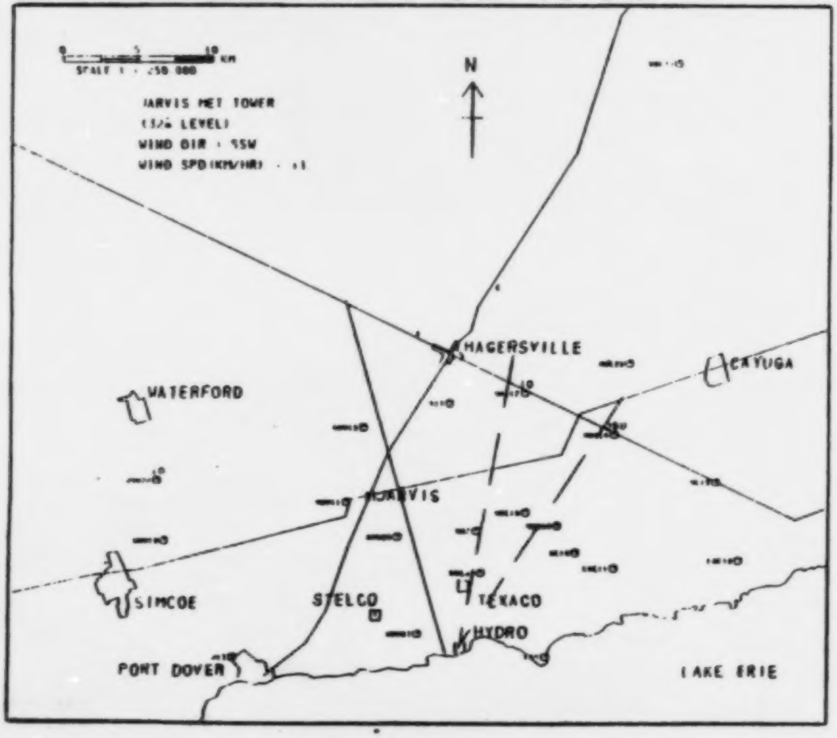



Diurnal Variation of SO$_2$ and Station Load August 2,1975

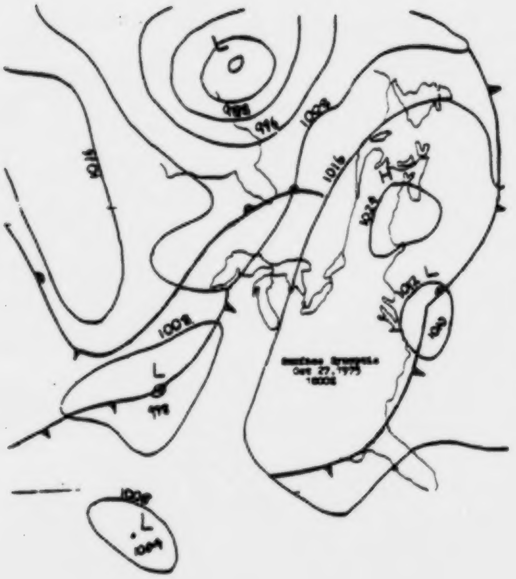

Wind Speed and Direction

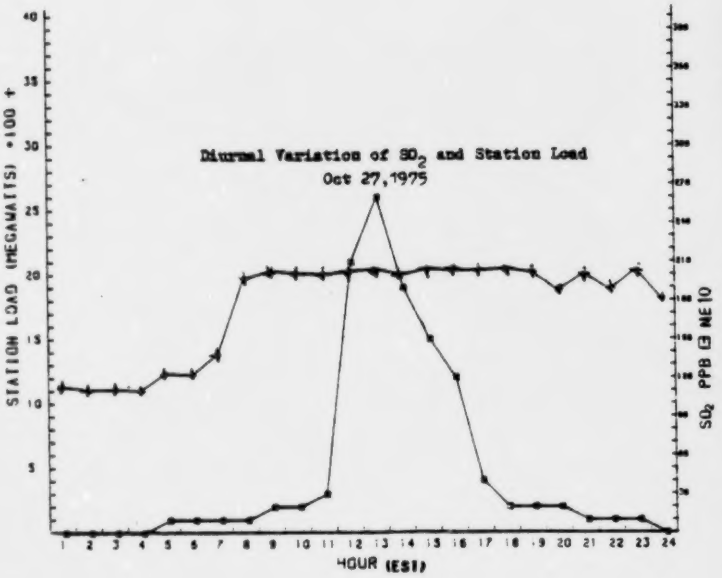
2 AUG 1975

SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 2 AUG 75



SO_2 EPISODE OF OCTOBER 27,1975

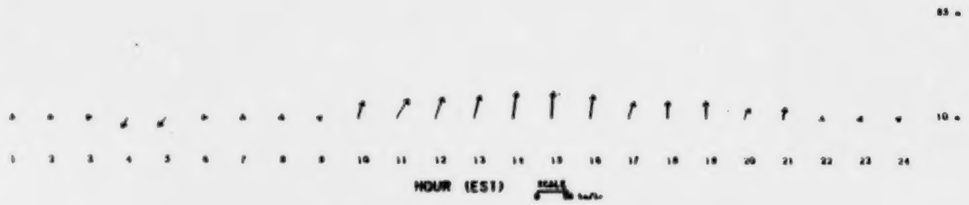




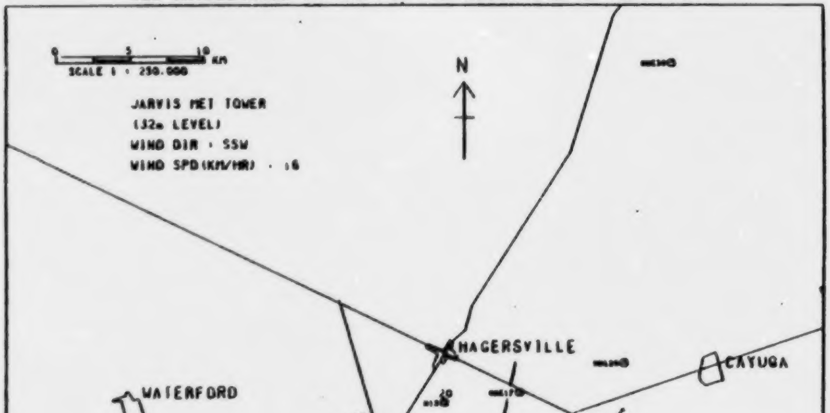
Diurnal Variation of SO_2 and Station Load
Oct 27,1975

Wind Speed and Direction

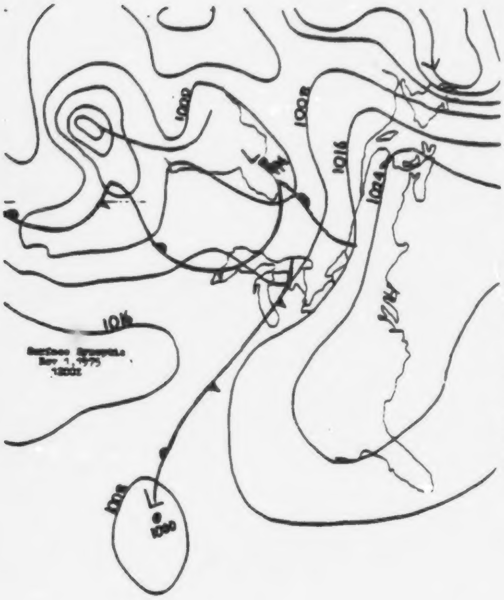
27 OCT 1975

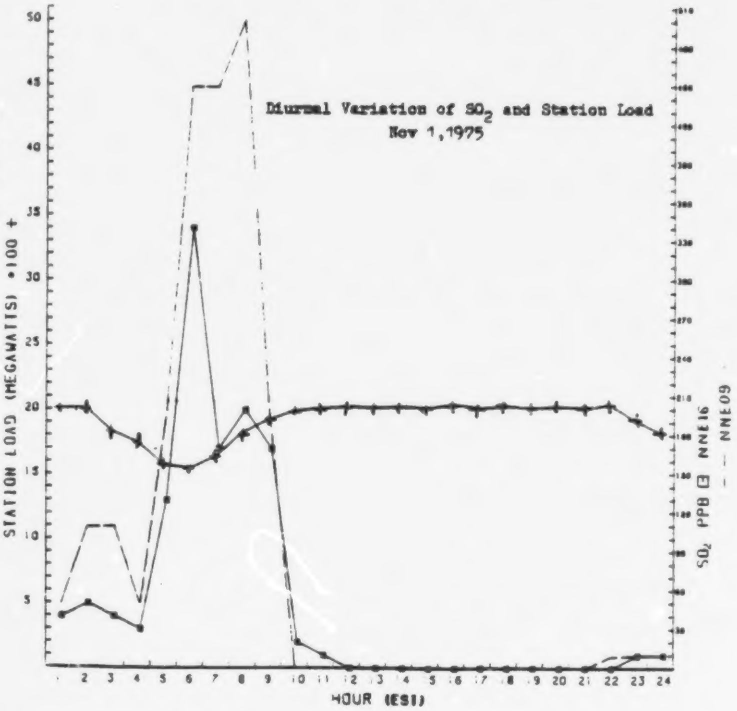


SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 27 OCT 75



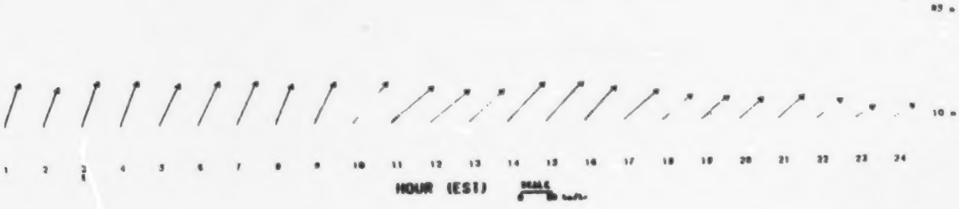
SO$_2$ EPISODE OF NOVEMBER 1,1975



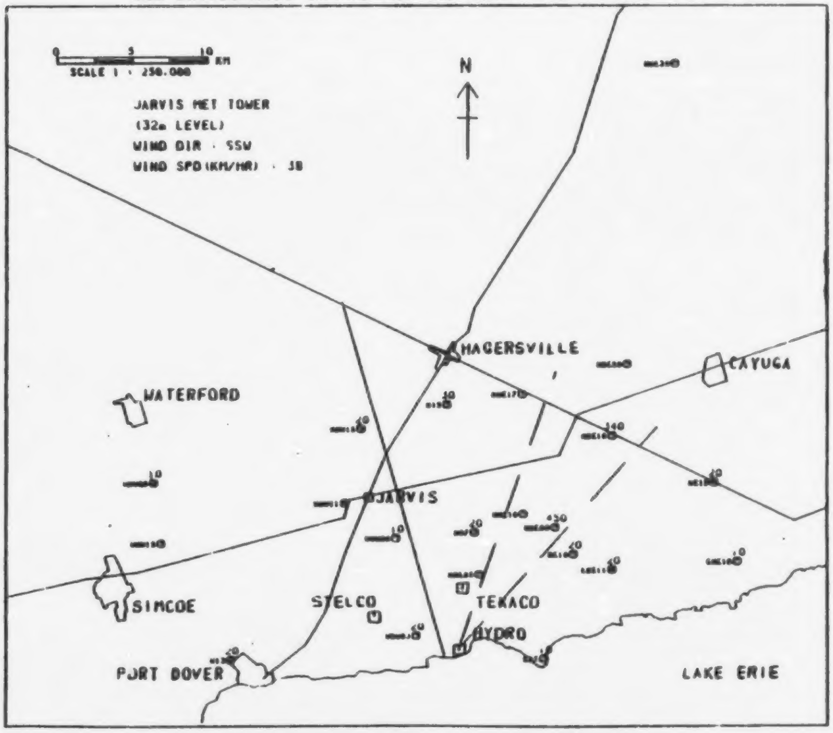

Diurnal Variation of SO$_2$ and Station Load
Nov 1,1975

Wind Speed and Direction

1 NOV 1975



SO2 EXCEEDANCES IN PPB FOR THE HOUR 6 OF 1 NOV 75



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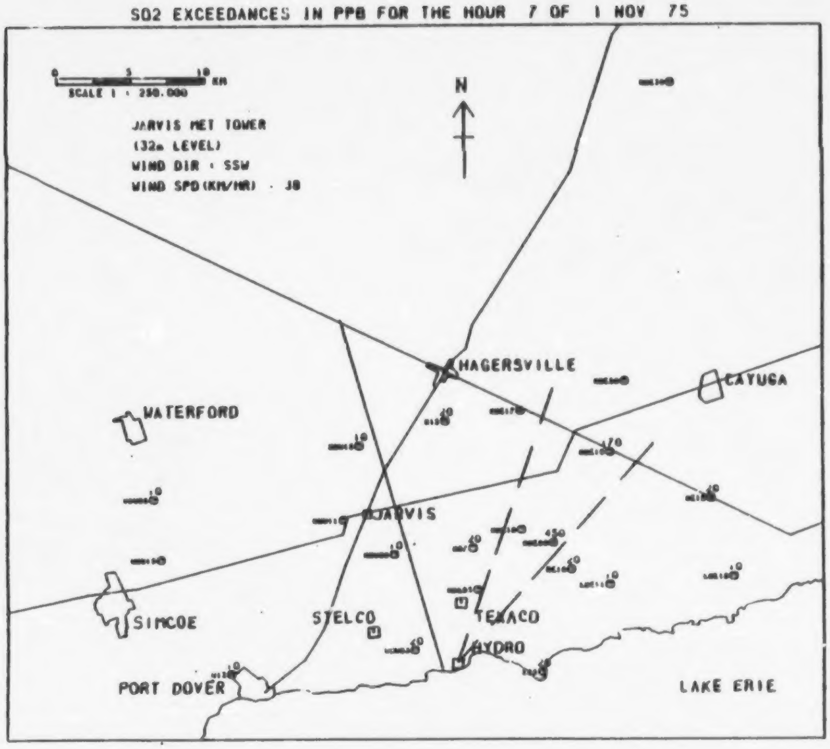
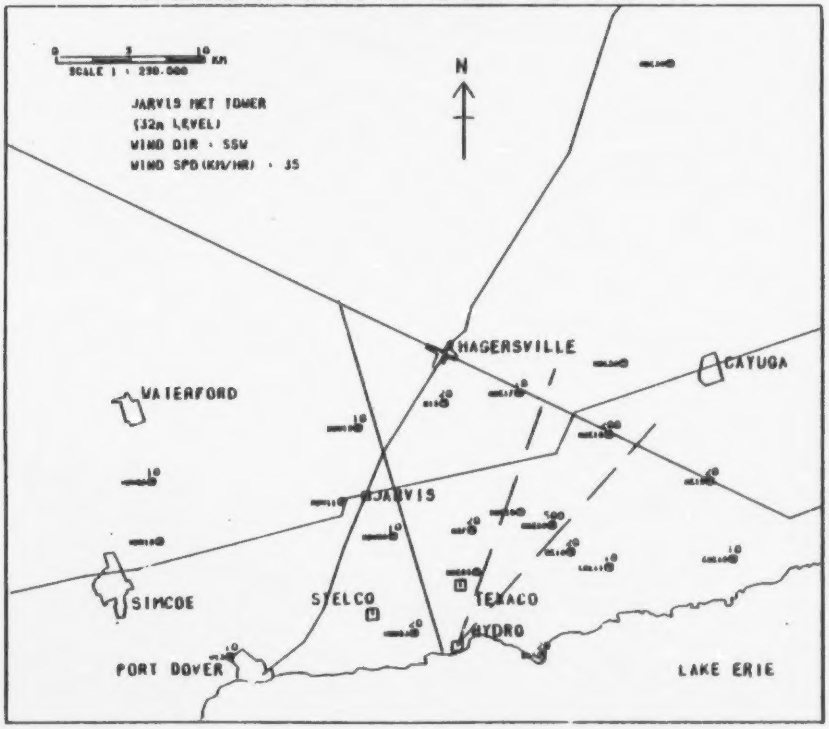
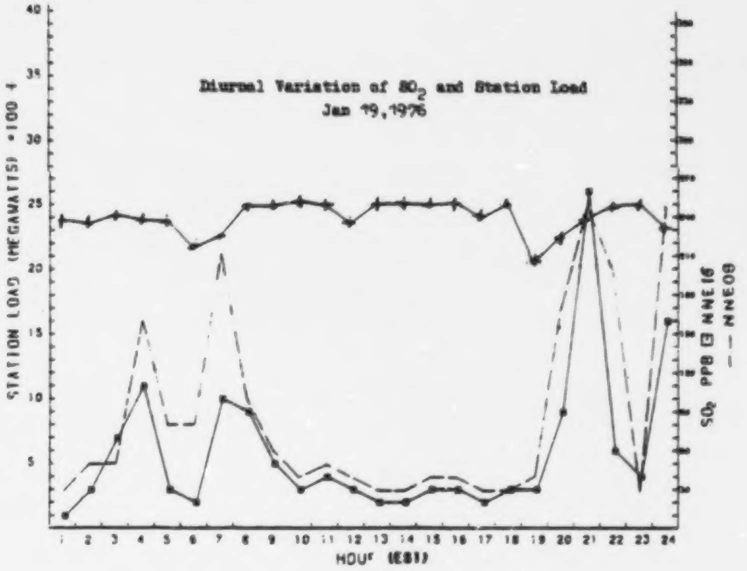
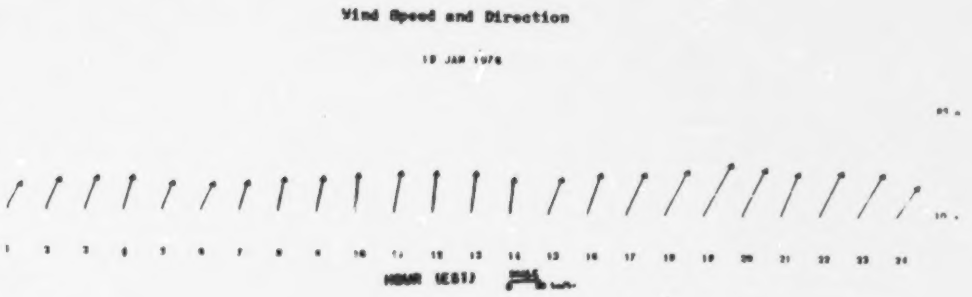


SO2 EXCEEDANCES IN PPB FOR THE HOUR 8 OF 1 NOV 75

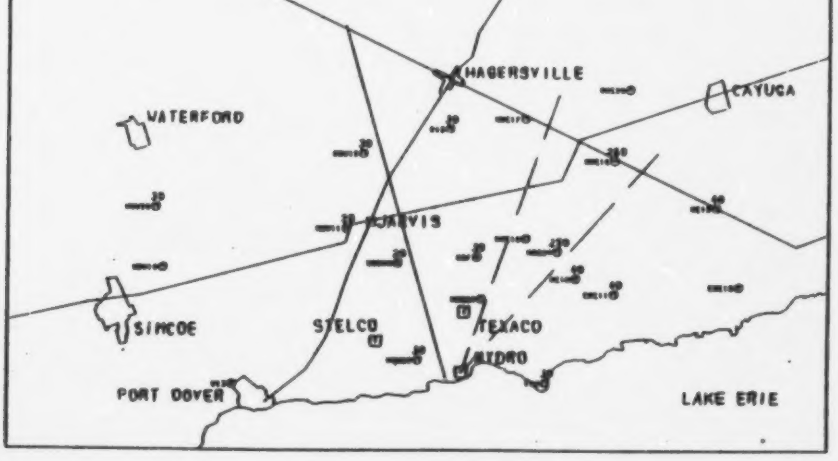


SO_2 EPISODE OF JANUARY 19,1976

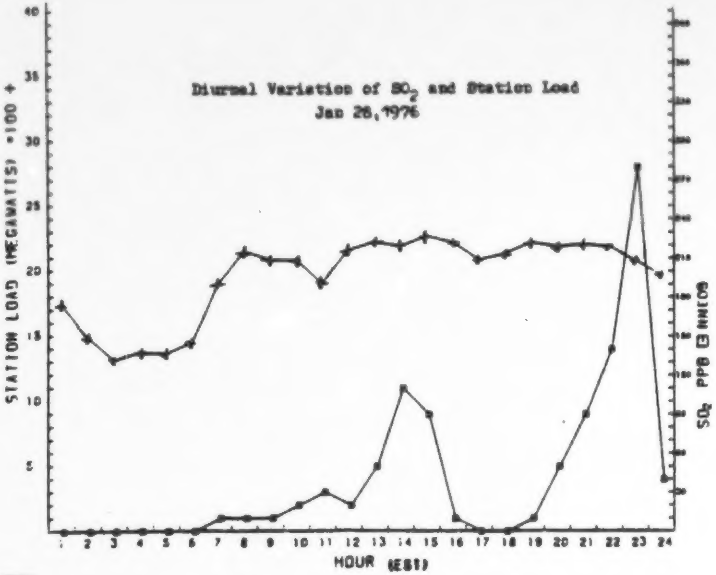


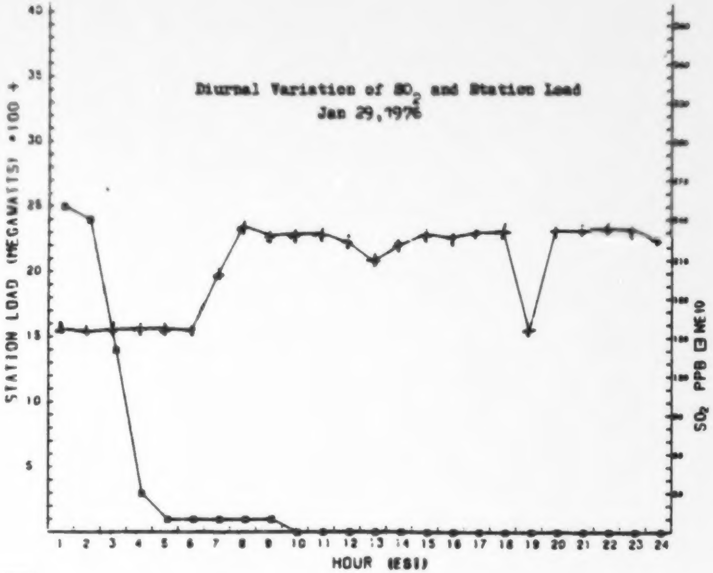


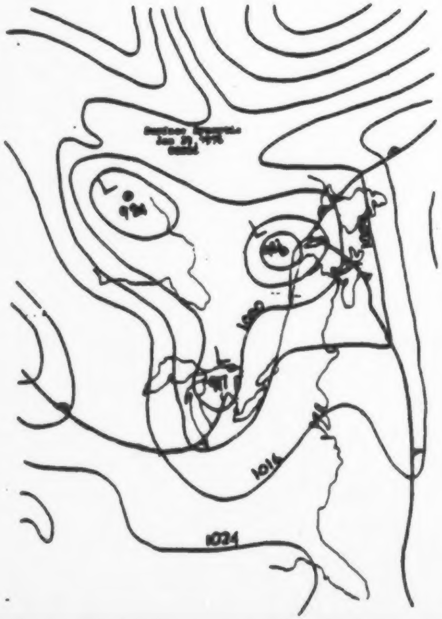
SO2 EXCEEDANCES IN PPB FOR THE HOUR 21 OF 19 JAN 76



SO2 EPISODE OF JANUARY 28 and 29,1976

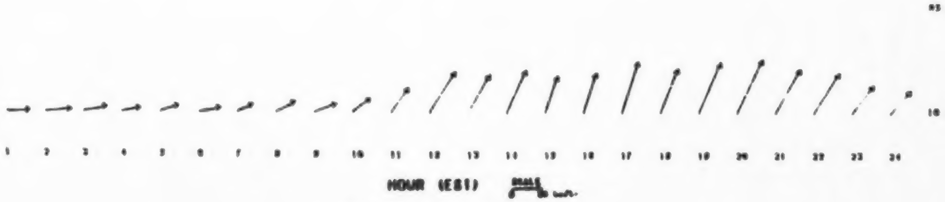

Diurnal Variation of SO_2 and Station Load
Jan 28,1976


Diurnal Variation of SO_2 and Station Load
Jan 29,1976



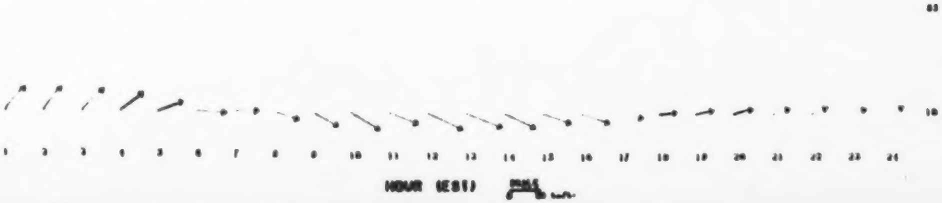
Wind Speed and Direction

28 JAN 1976

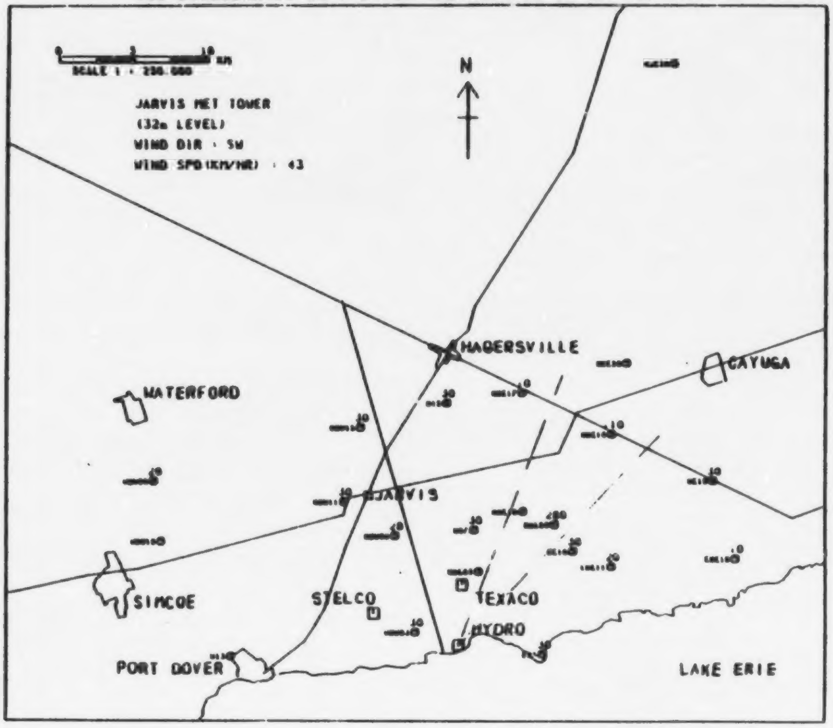


Wind Speed and Direction

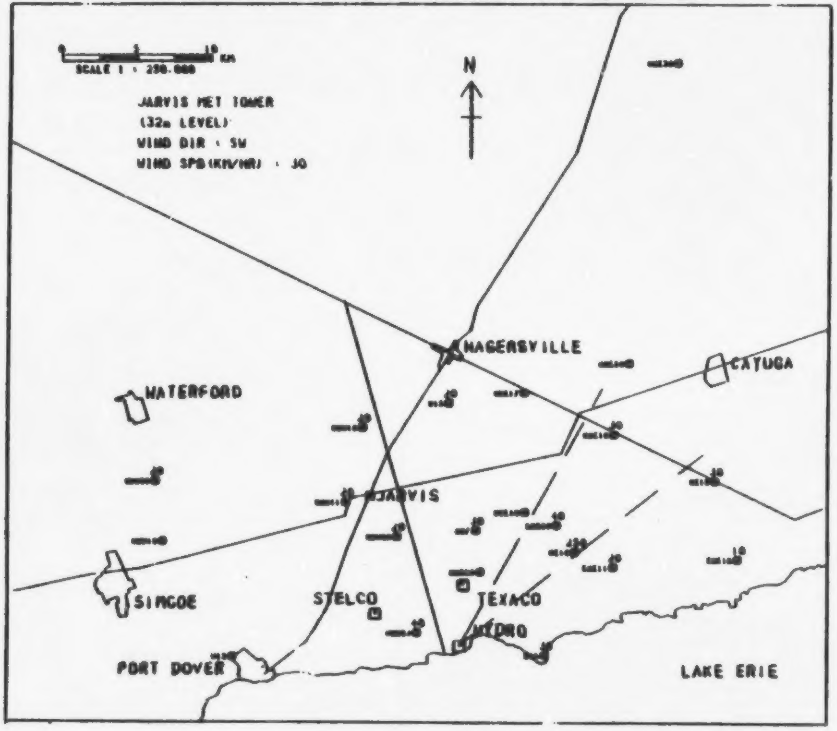
29 JAN 1976



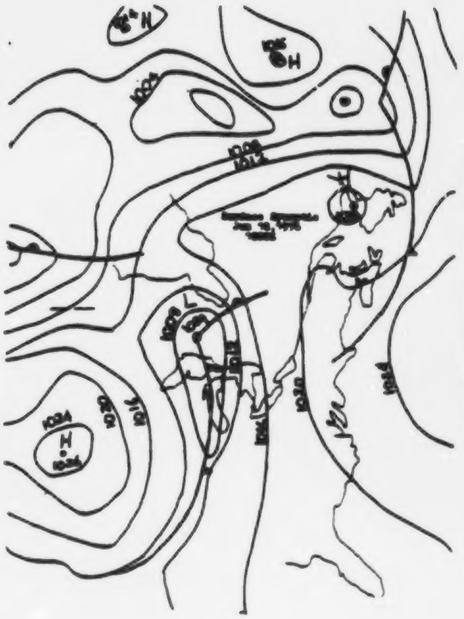
SO2 EXCEEDANCES IN PPB FOR THE HOUR 23 OF 28 JAN 76

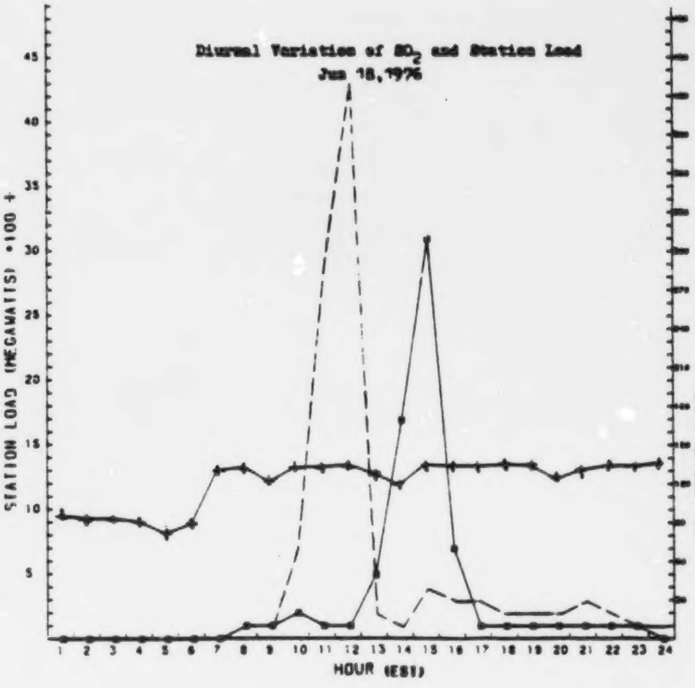


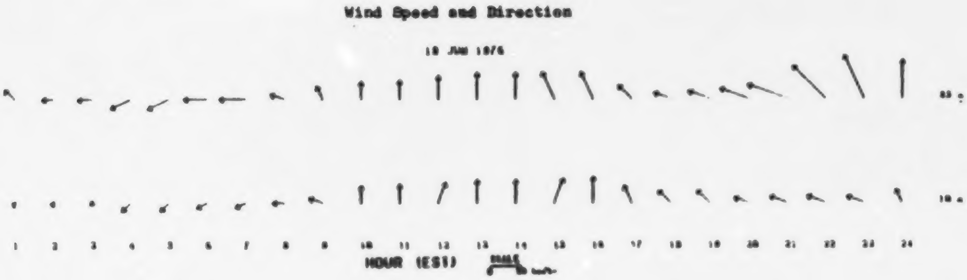
SO2 EXCEEDANCES IN PPB FOR THE HOUR 1 OF 29 JAN 76



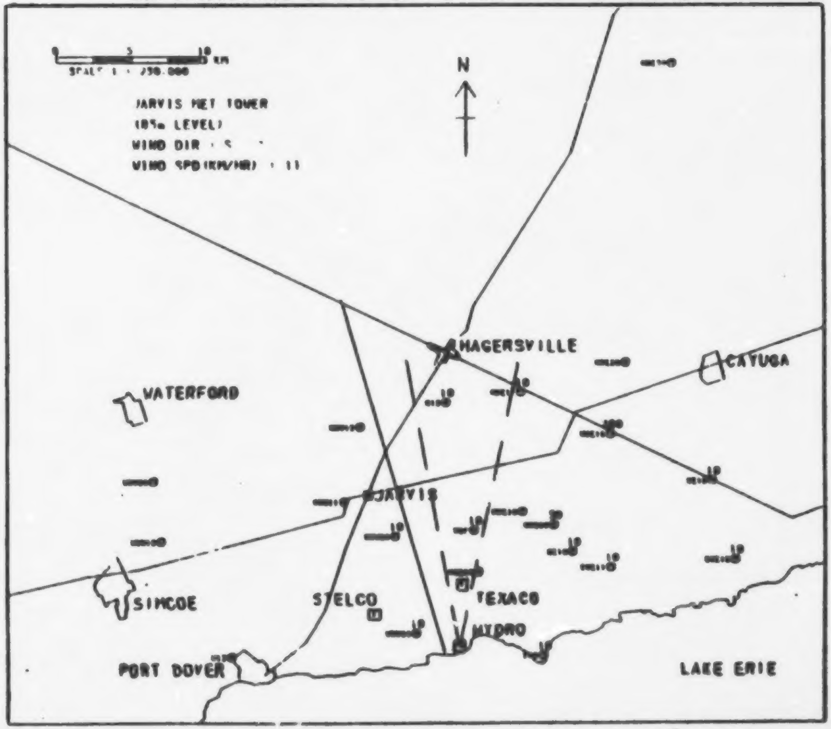
SO$_2$ EPISODE OF JUNE 18,1976



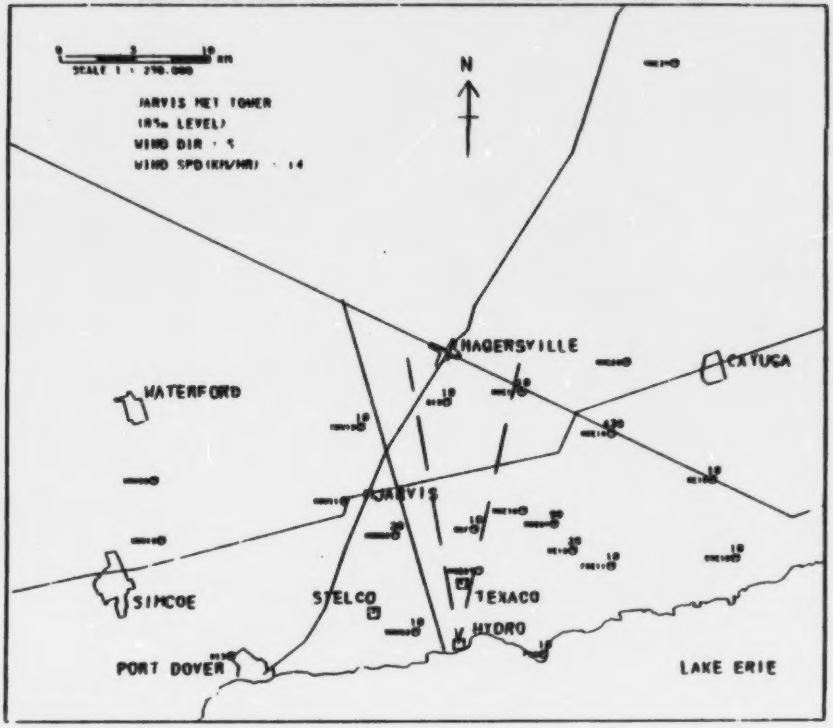




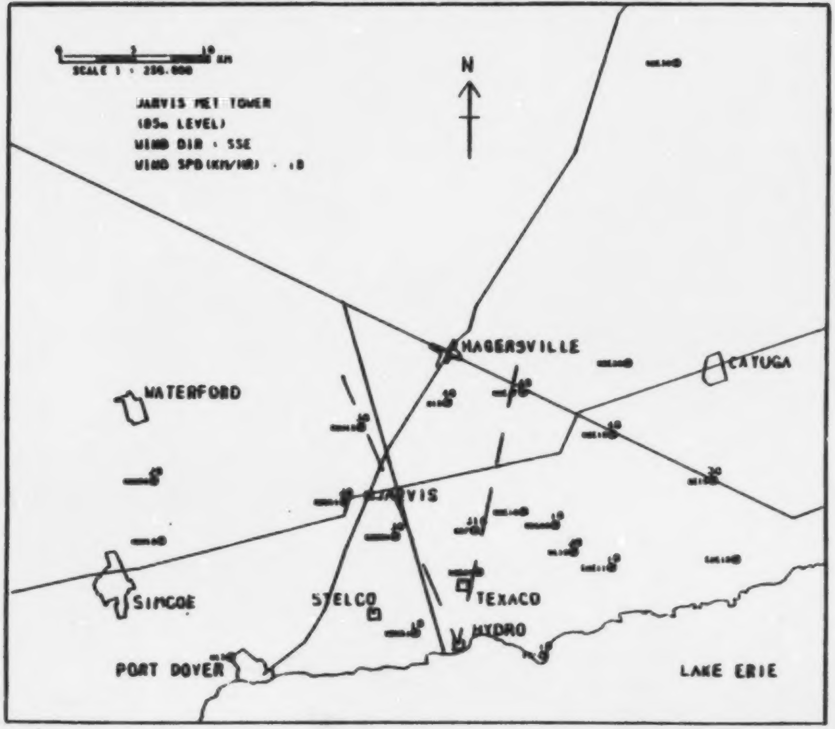
SO2 EXCEEDANCES IN PPB FOR THE HOUR 11 OF 18 JUNE 76



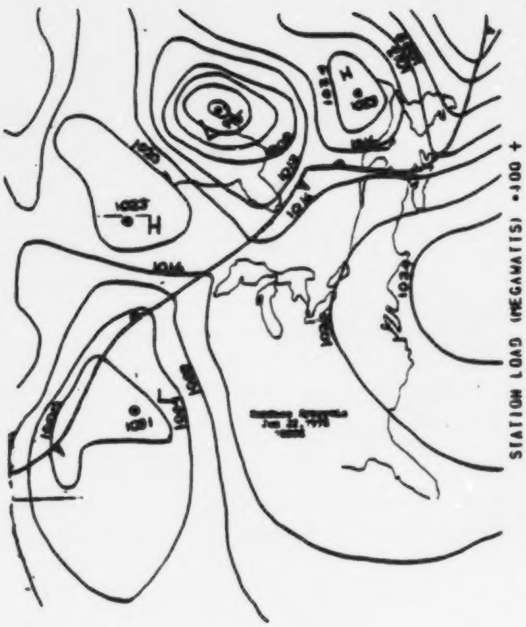
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 18 JUNE 76

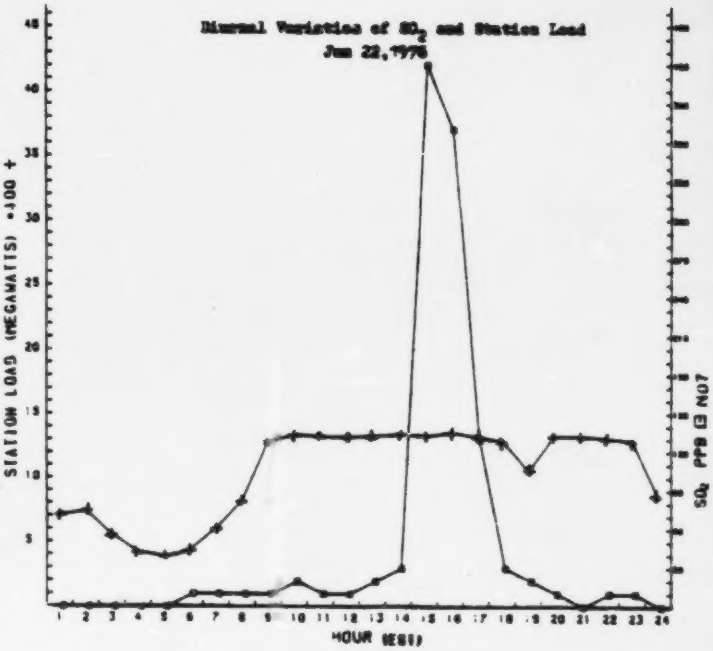


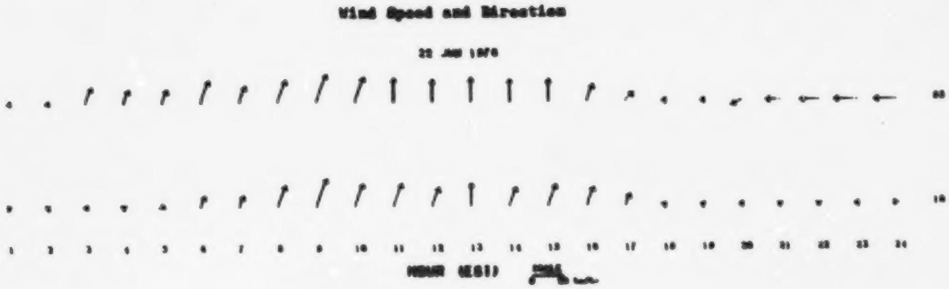
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 18 JUNE 76



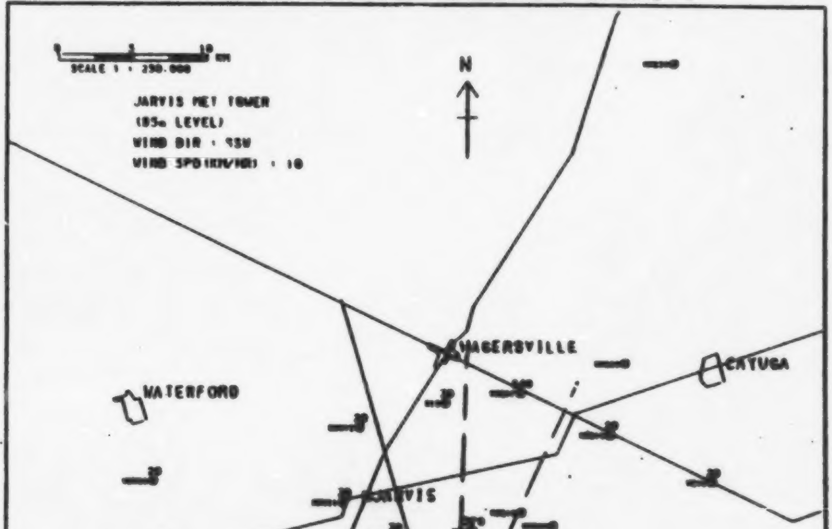
SO$_2$ EPISODE OF JUNE 22,1976



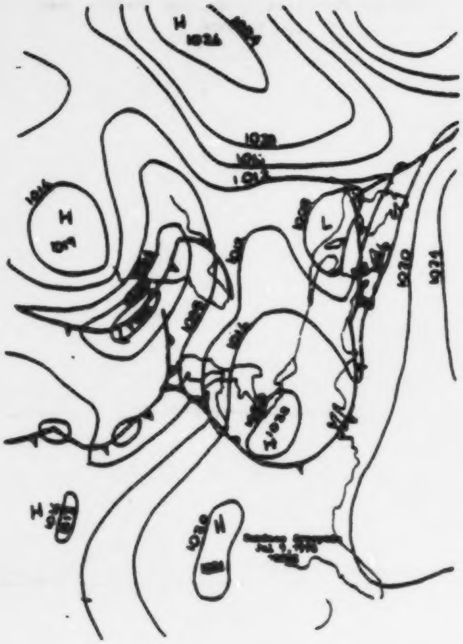


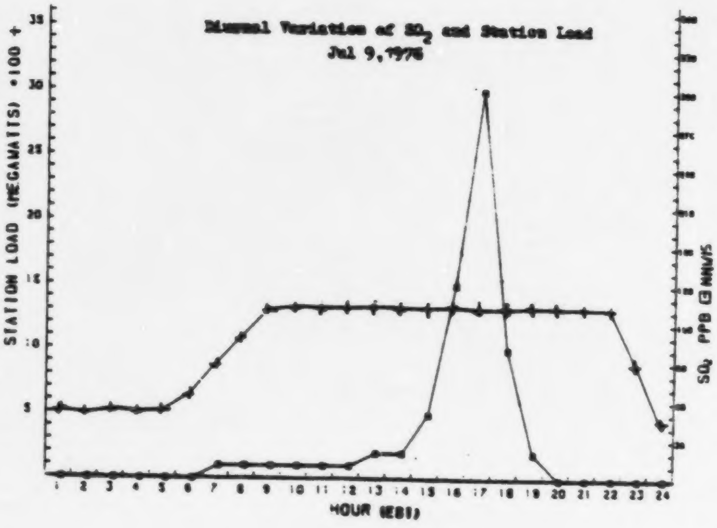


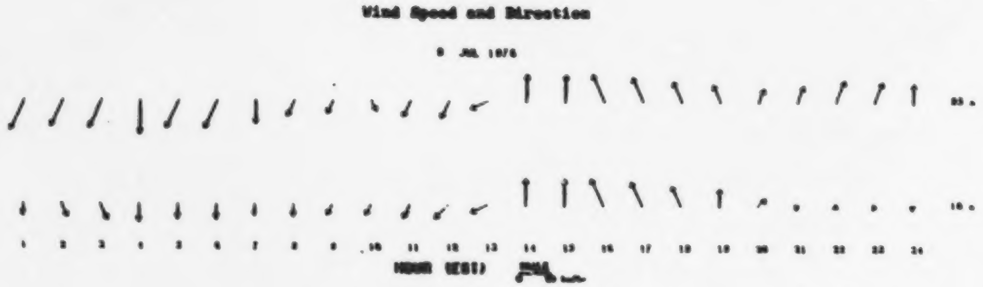
SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 22 JUNE 76



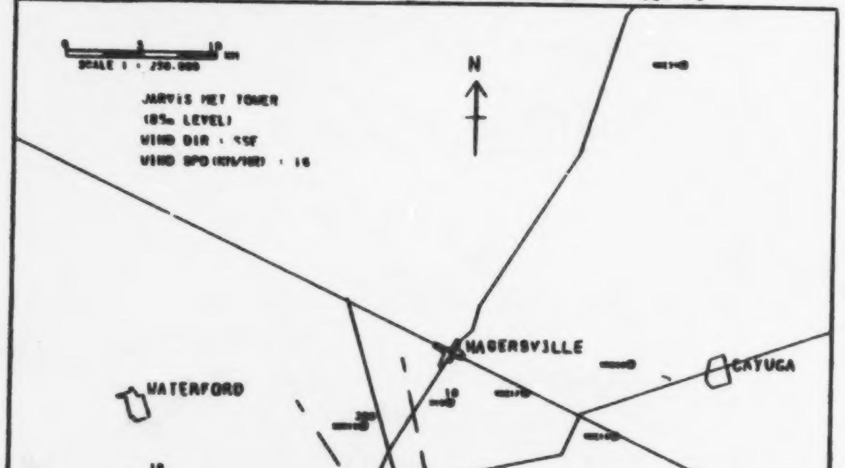
SO$_2$ EPISODE OF JULY 9,1976



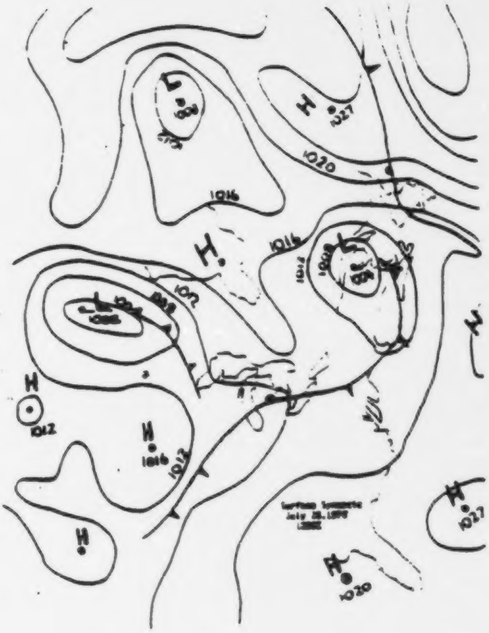


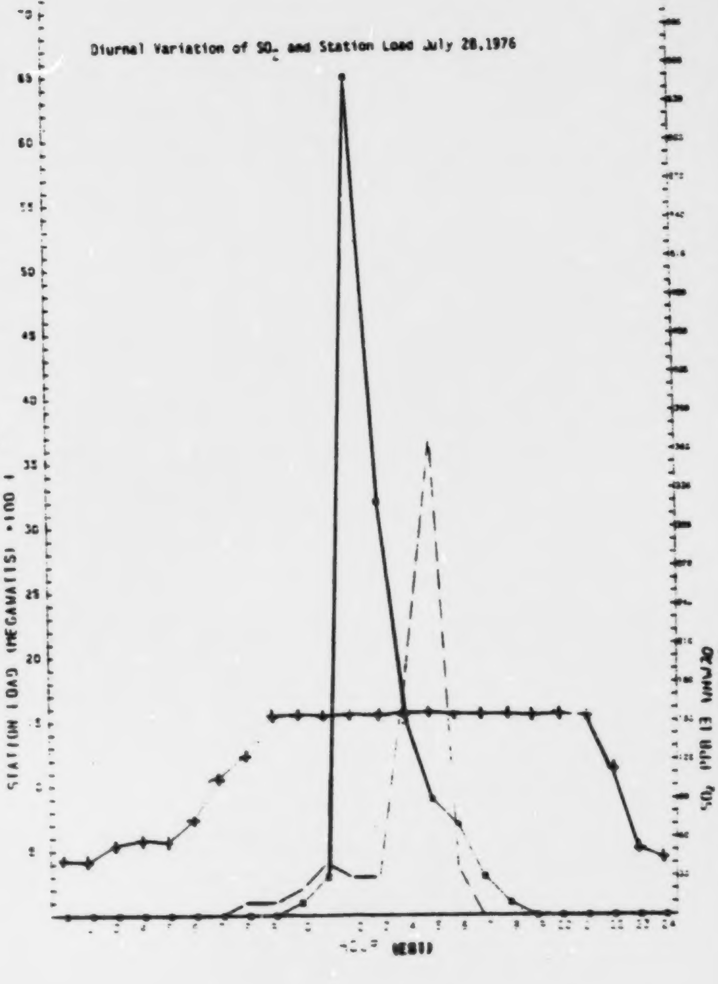


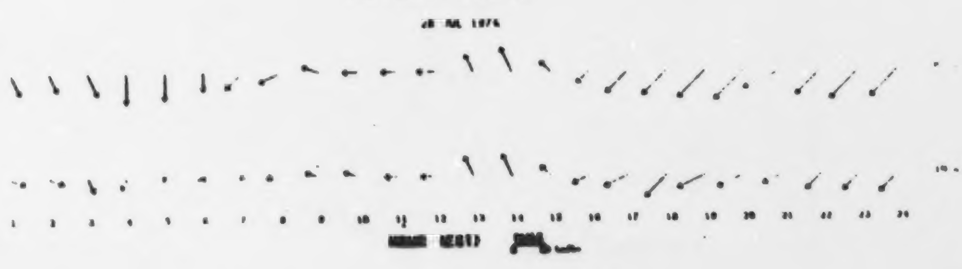
SO2 EXCEEDANCES IN PPB FOR THE HOUR 17 OF 9 JULY 76



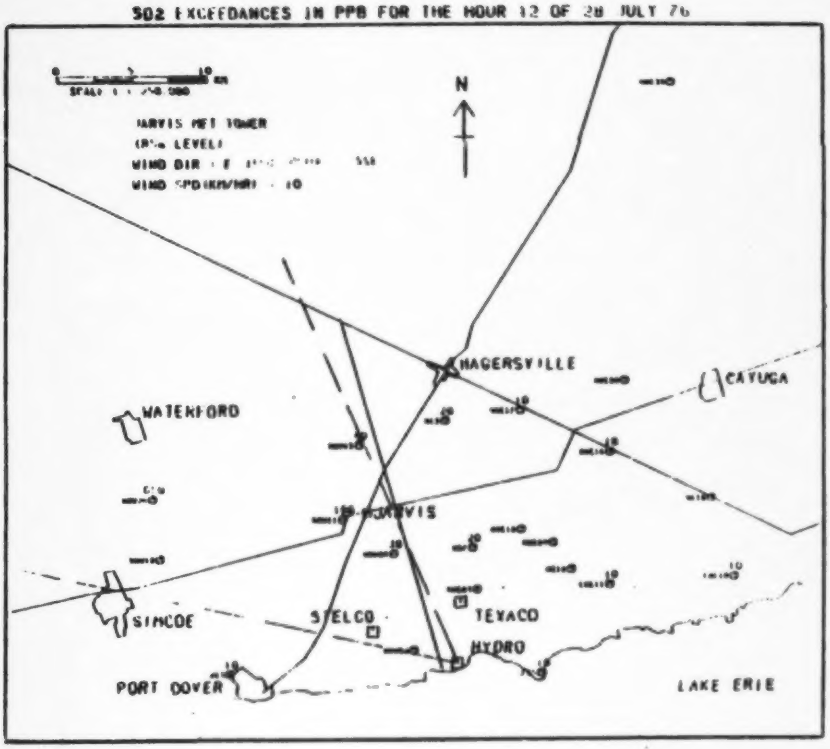
SO$_2$ EPISODE OF JULY 28,1976



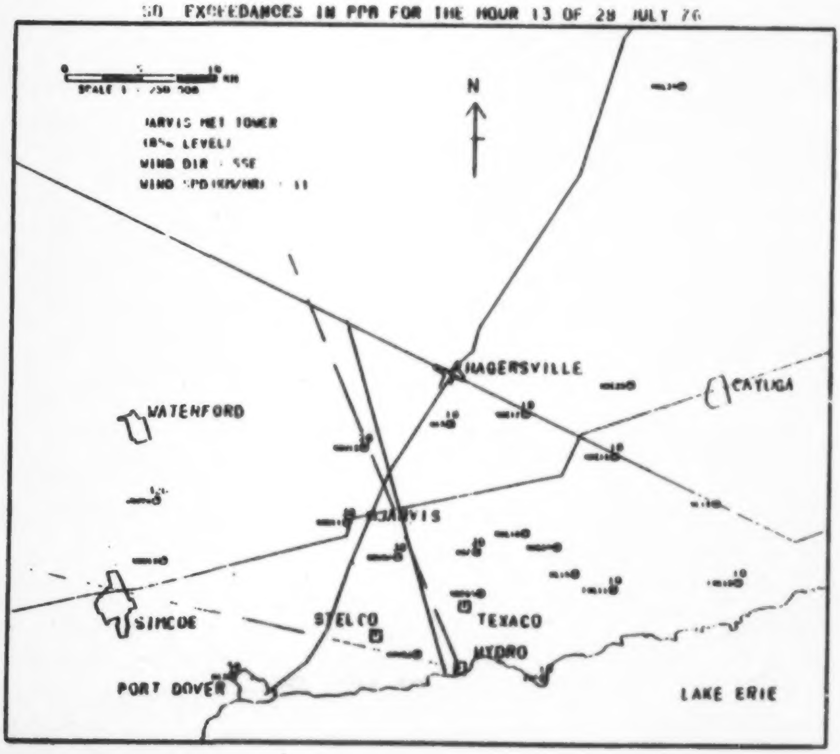




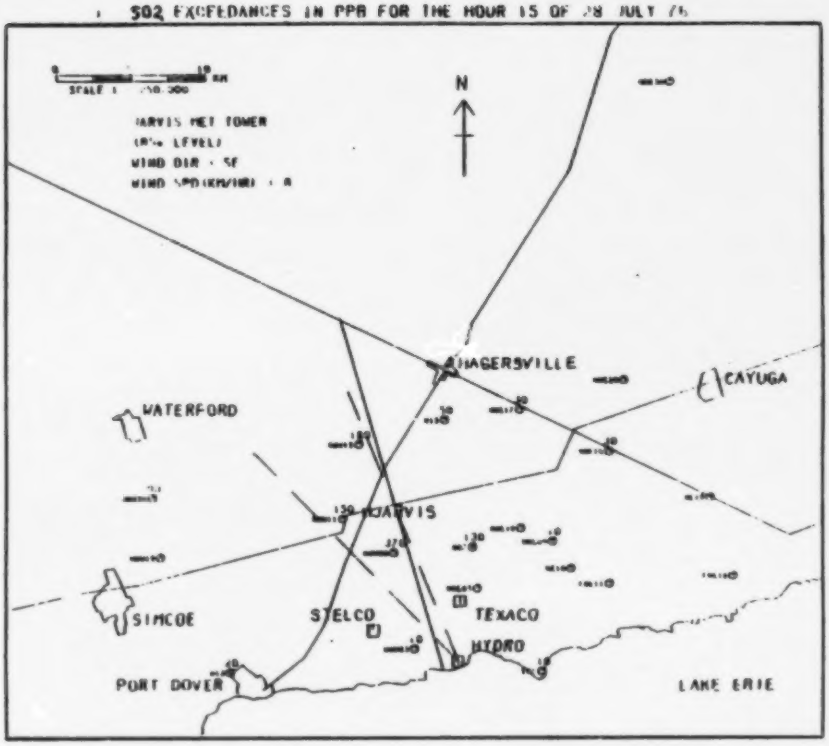
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 28 JULY 76



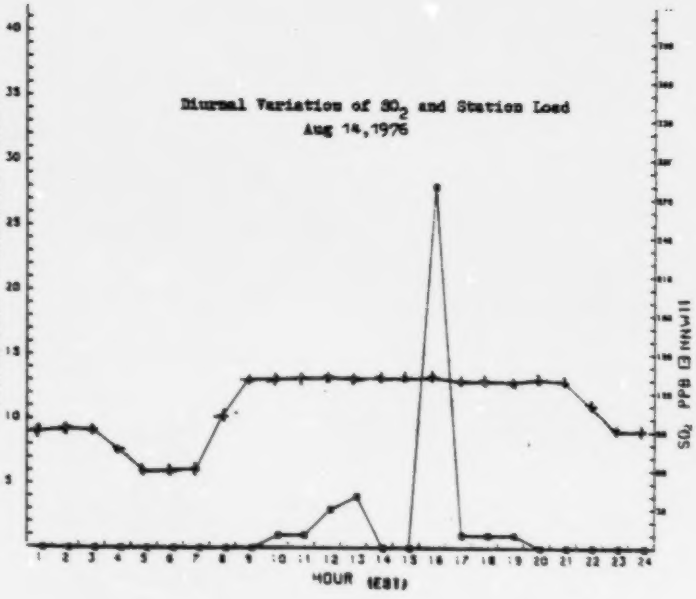
SO EXCEEDANCES IN PPB FOR THE HOUR 13 OF 28 JULY 76

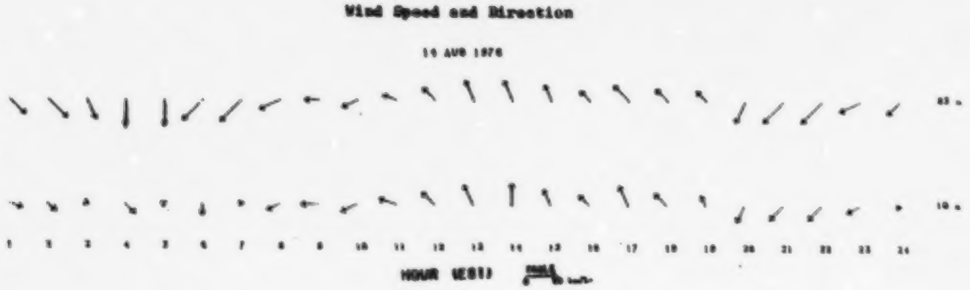


SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 28 JULY 76

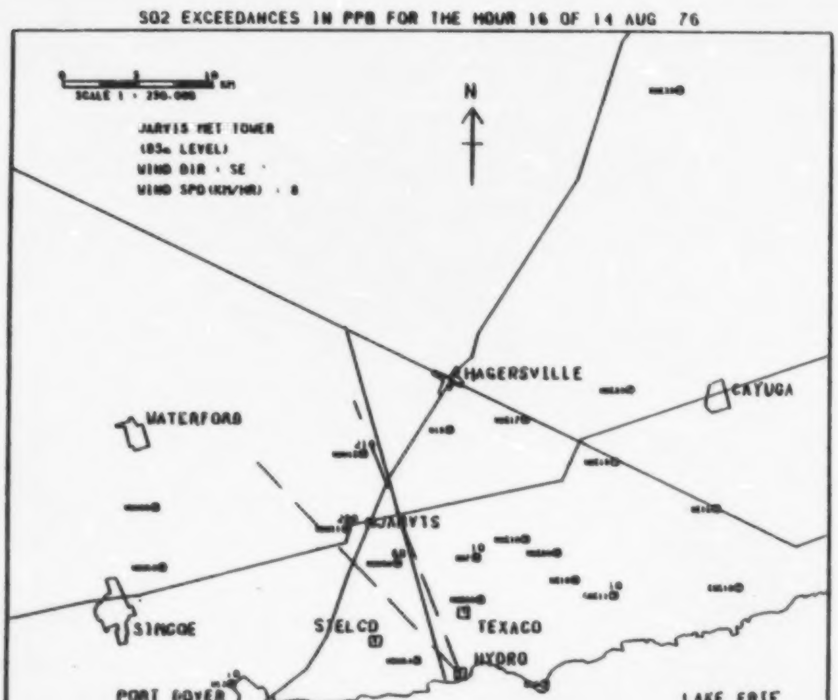


SO_2 EPISODE OF AUGUST 14,1976

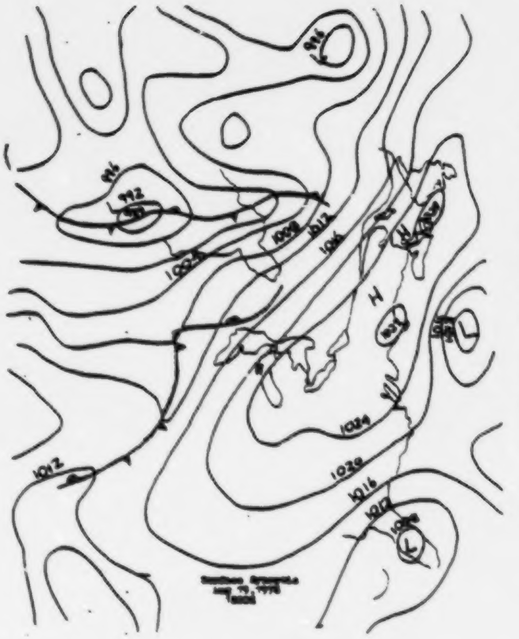


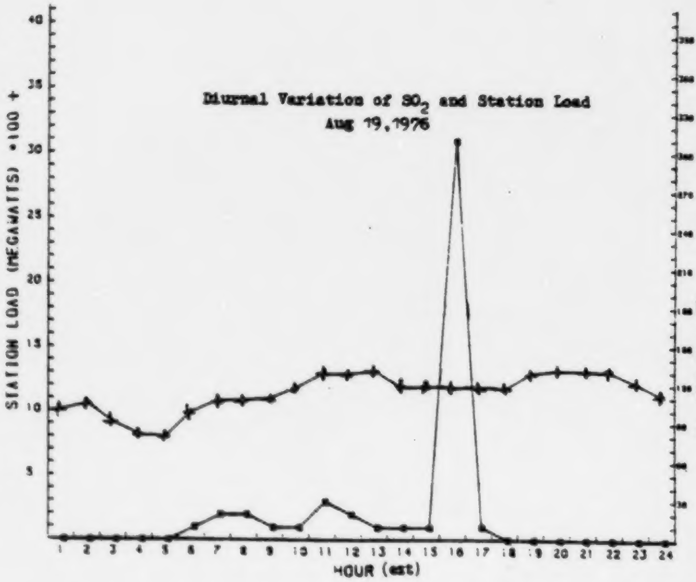


SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 14 AUG 76



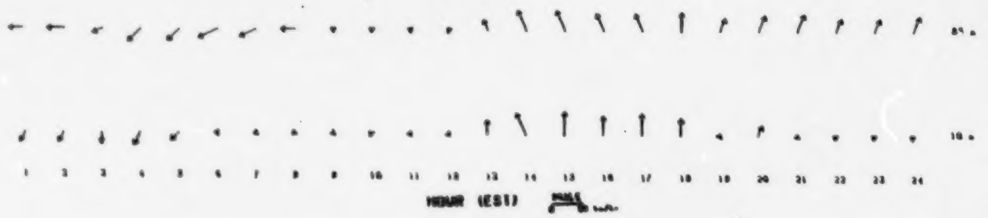
SO$_2$ EPISODE OF AUGUST 19,1976



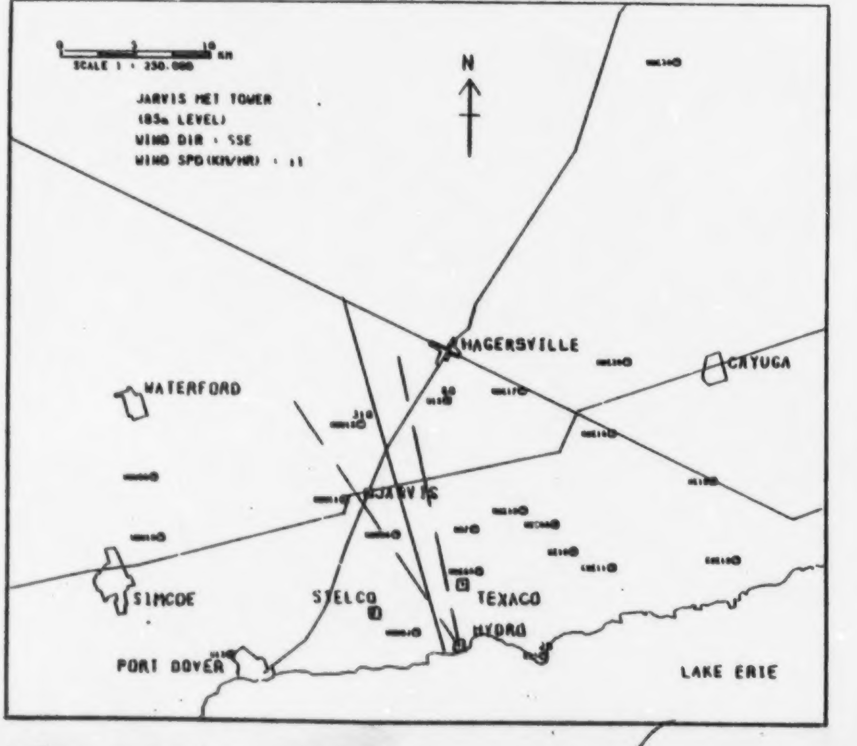


Wind Speed and Direction

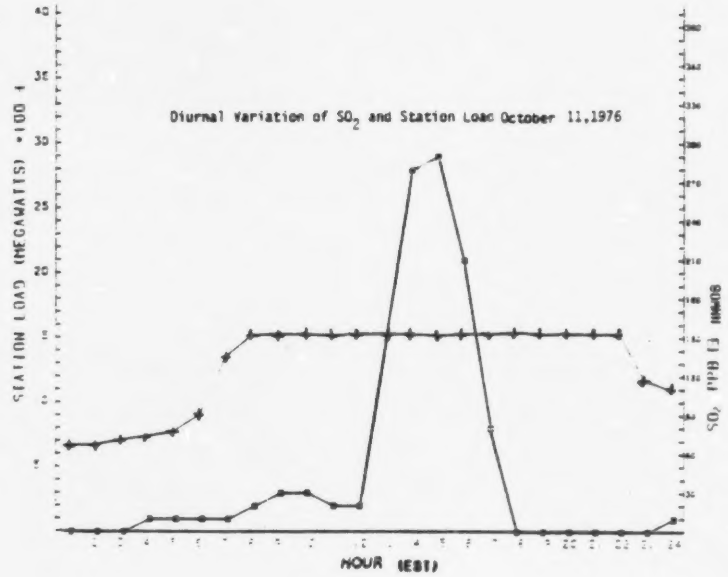
19 AUG 1976

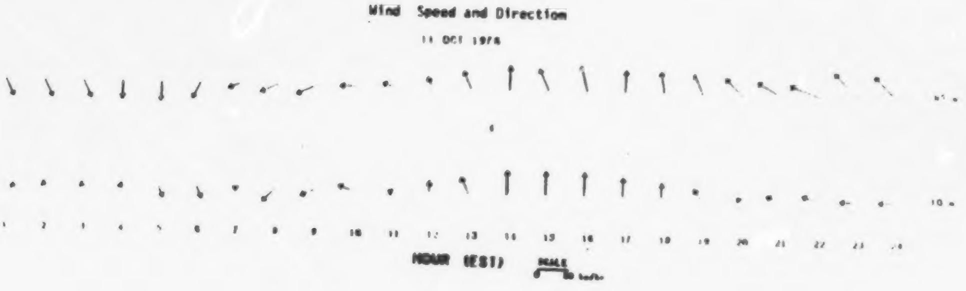


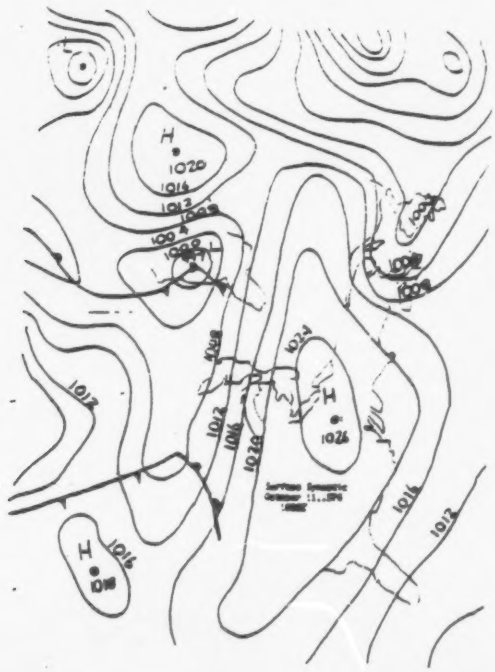
SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 19 AUG 76



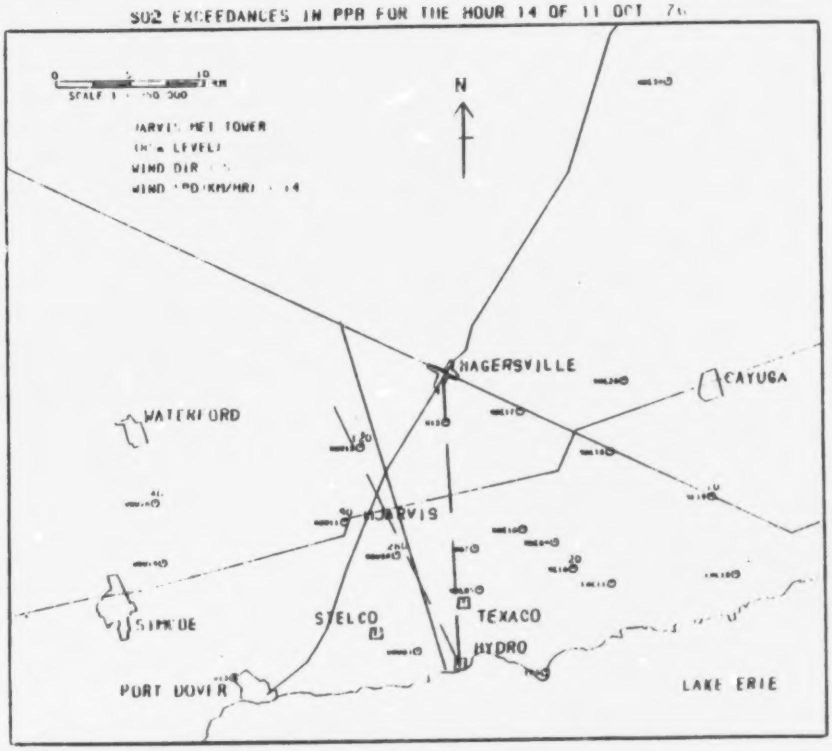
SO$_2$ EPISODE OF OCTOBER 11,1976



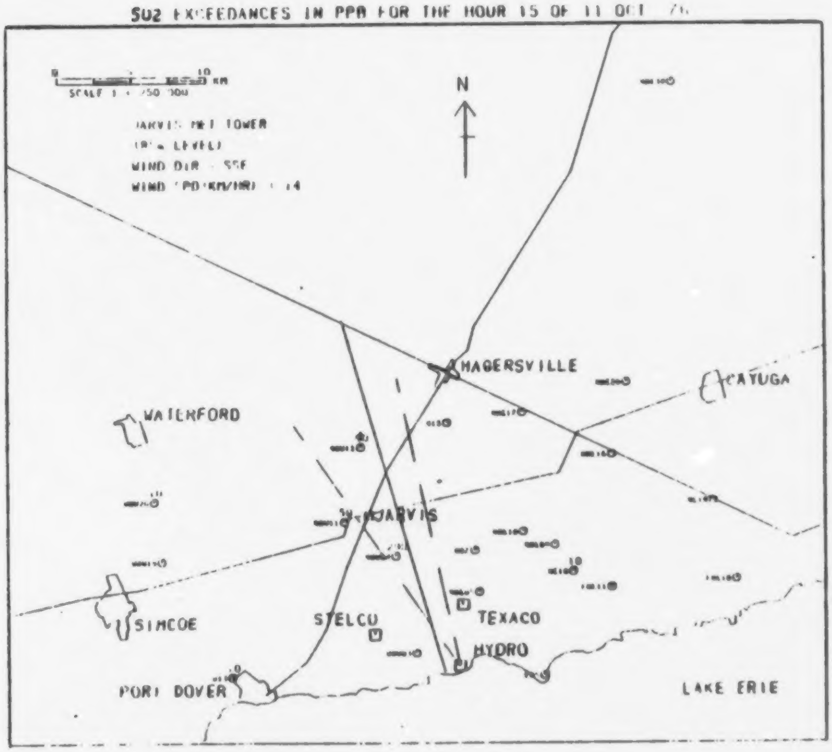




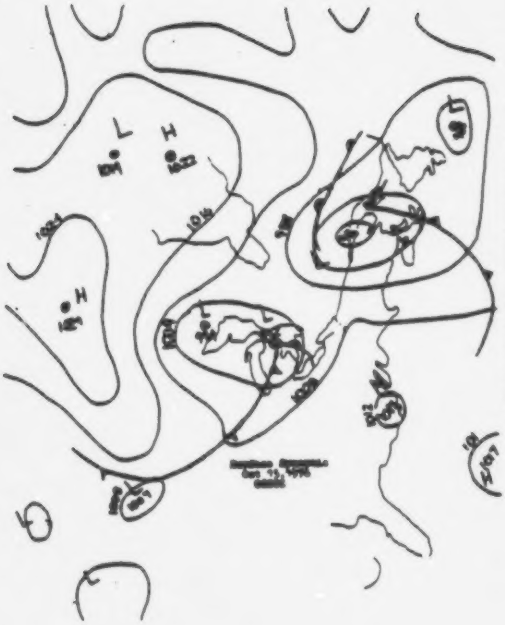
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 11 OCT 76

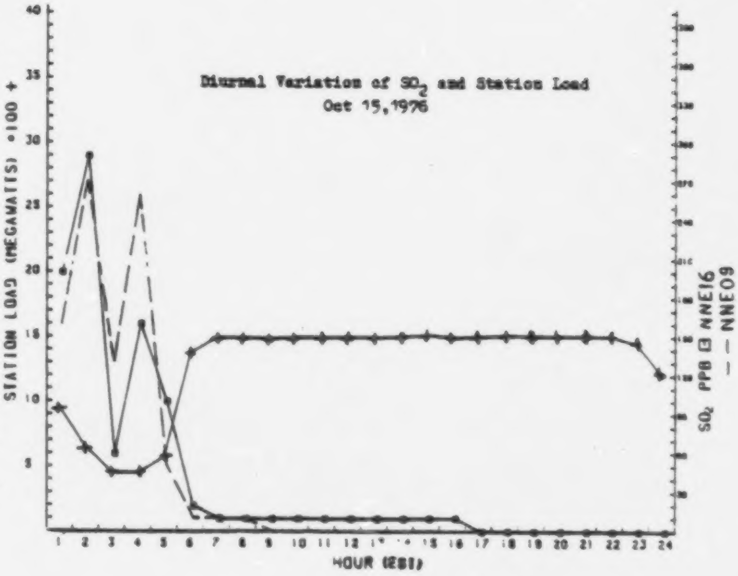


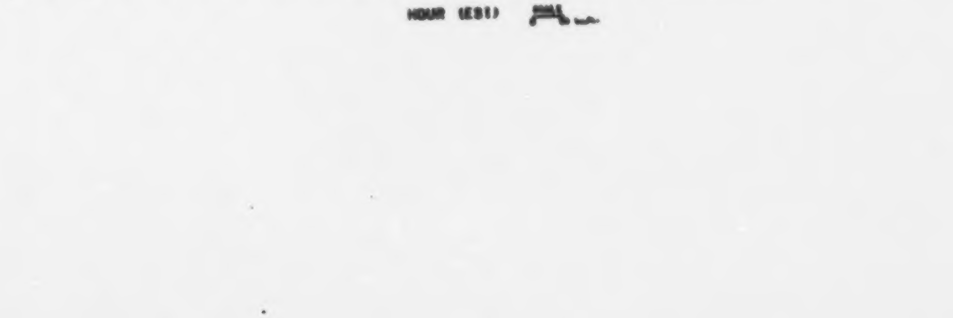
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 11 OCT 76



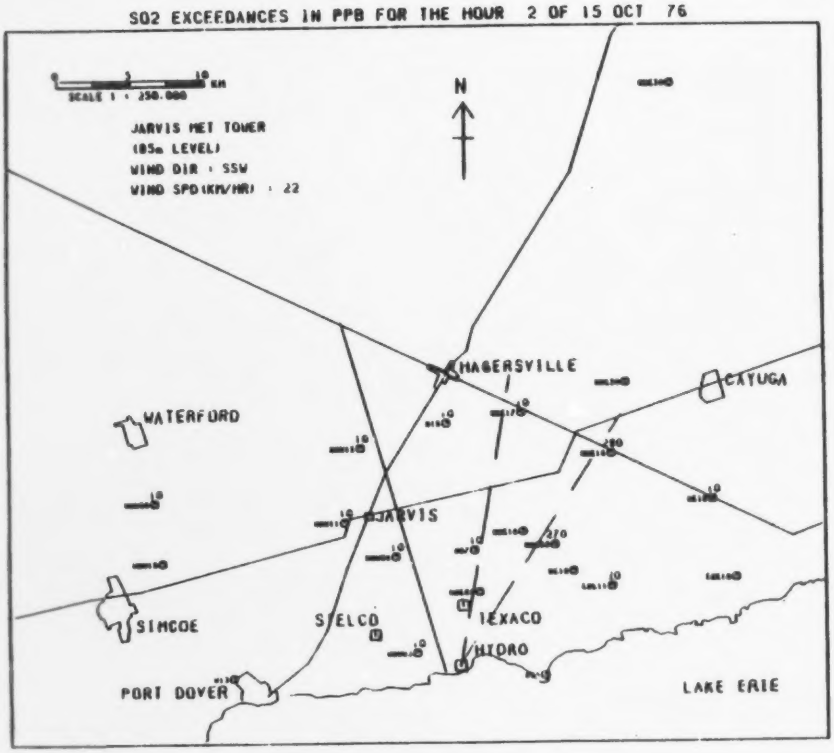
SO_2 EPISODE OF OCTOBER 15,1976



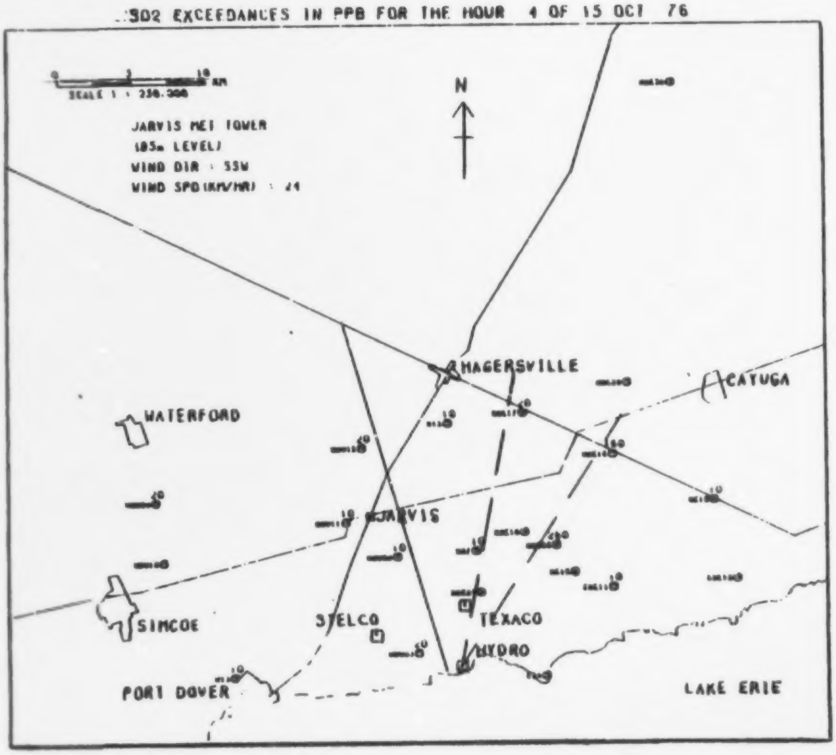




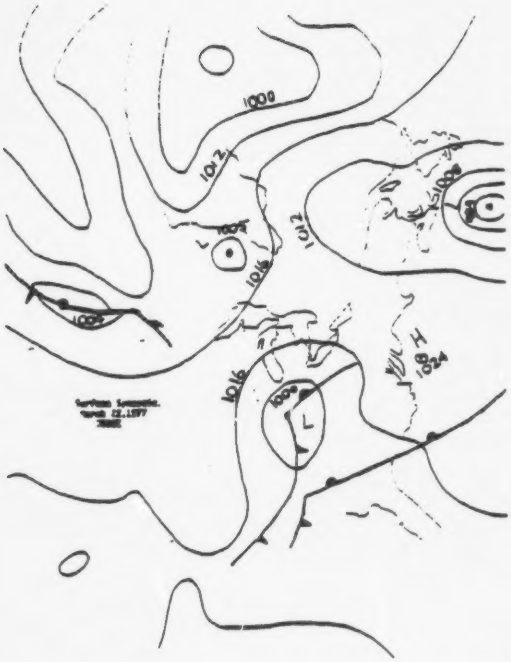
SO2 EXCEEDANCES IN PPB FOR THE HOUR 2 OF 15 OCT 76

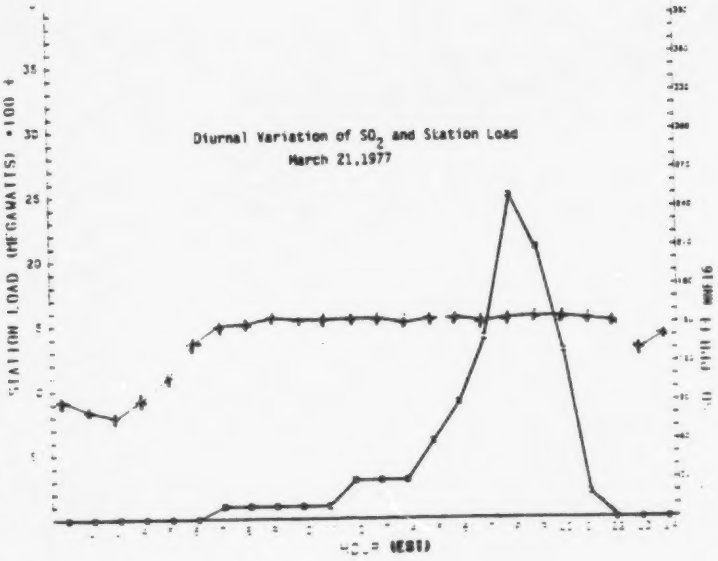


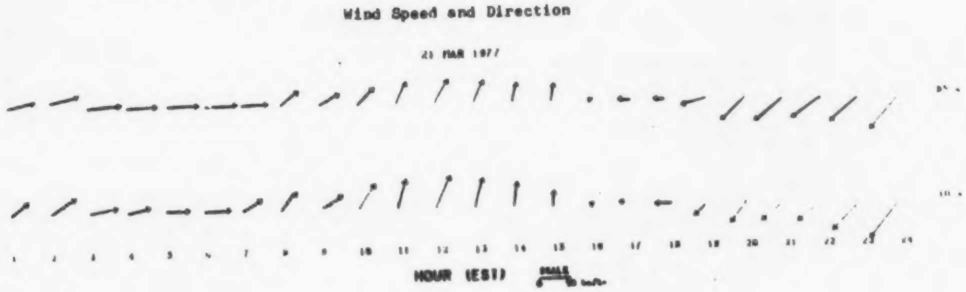
SO2 EXCEEDANCES IN PPB FOR THE HOUR 4 OF 15 OCT 76



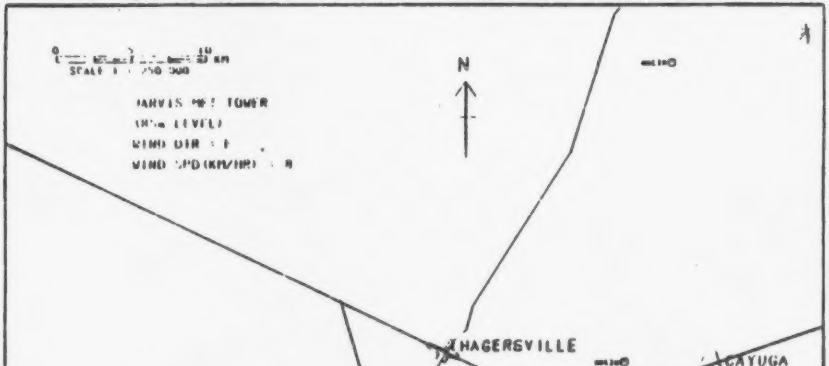
SO_2 EPISODE OF MARCH 21,1977



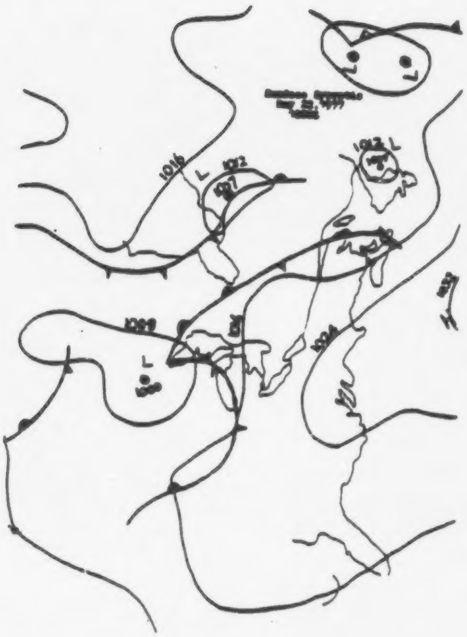


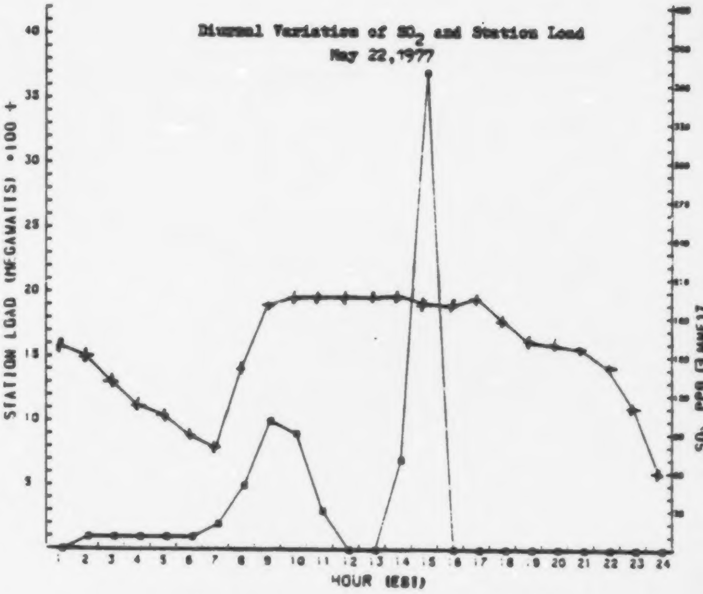


SO2 EXCEEDANCES IN PPB FOR THE HOUR 18 OF 21 MAR 77

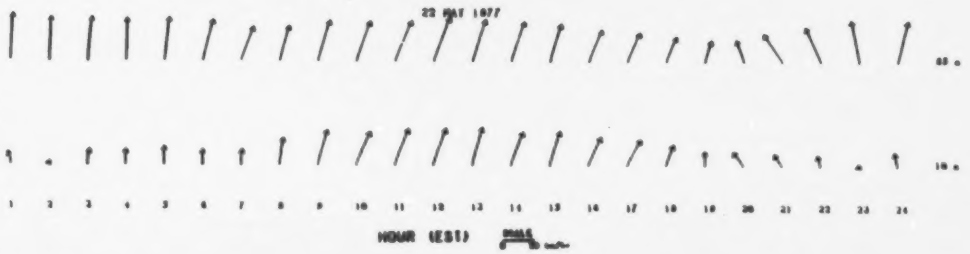


SO_2 EPISODE OF MAY 22,1977

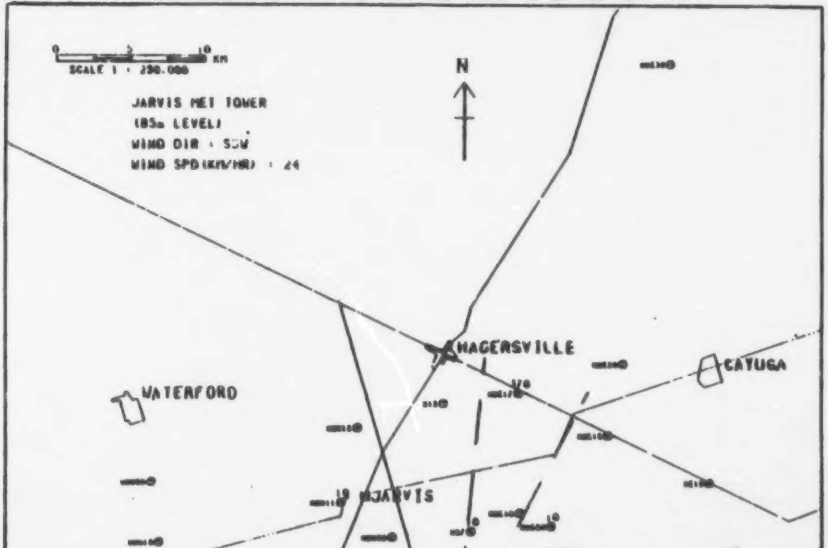




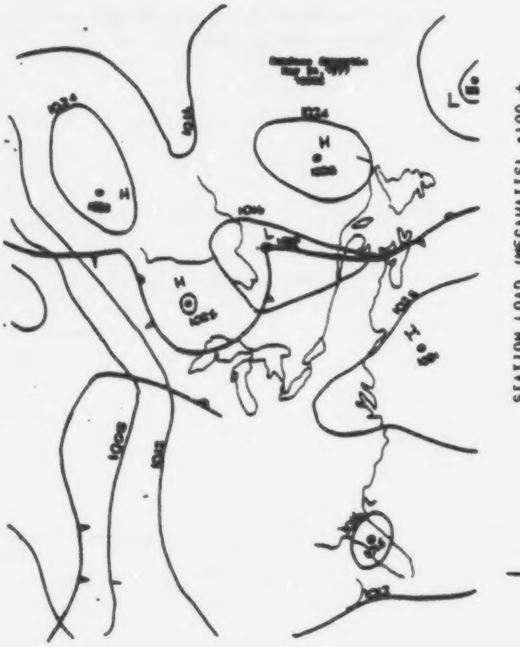
Wind Speed and Direction

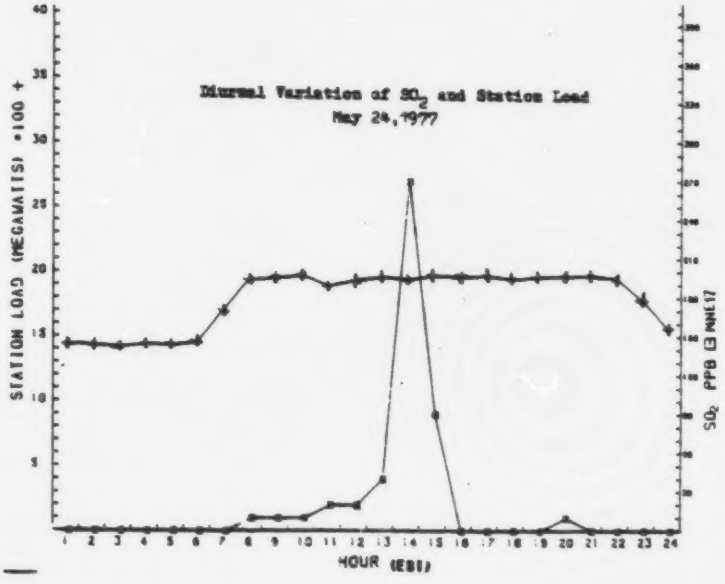


SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 22 MAY 77

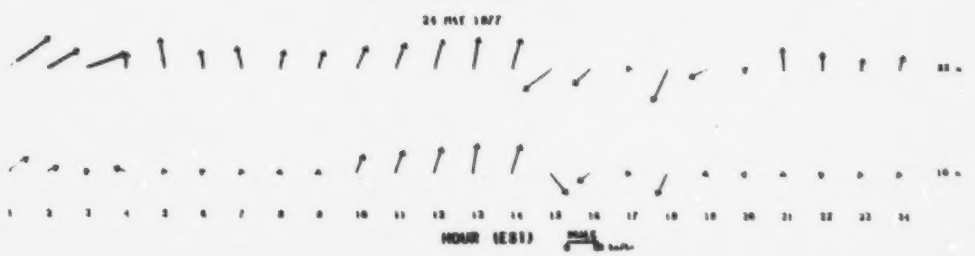


SO_2 EPISODE OF MAY 24,1977

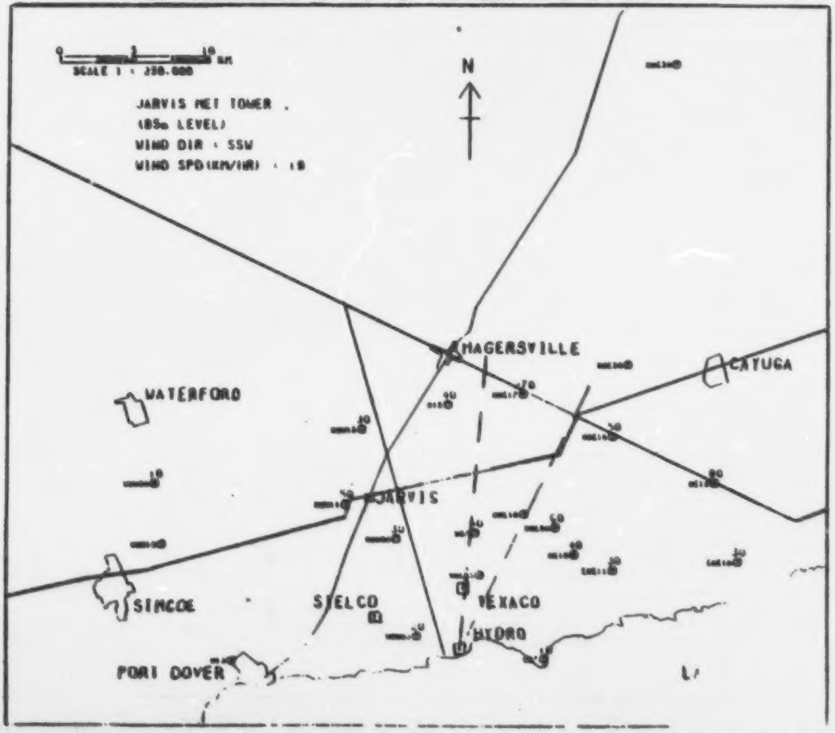




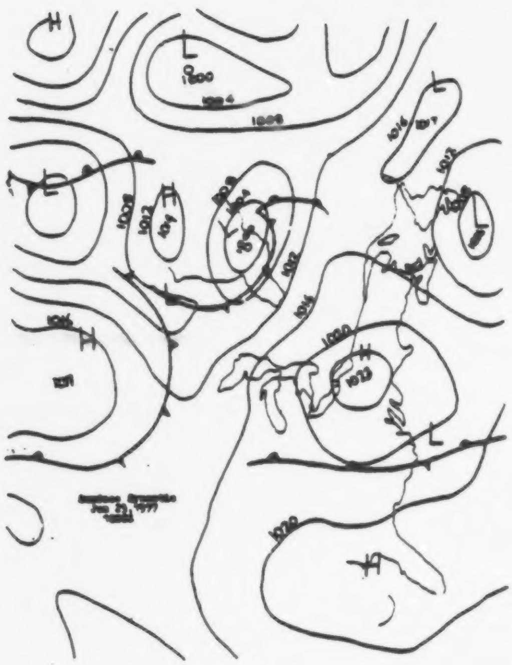
Wind Speed and Direction



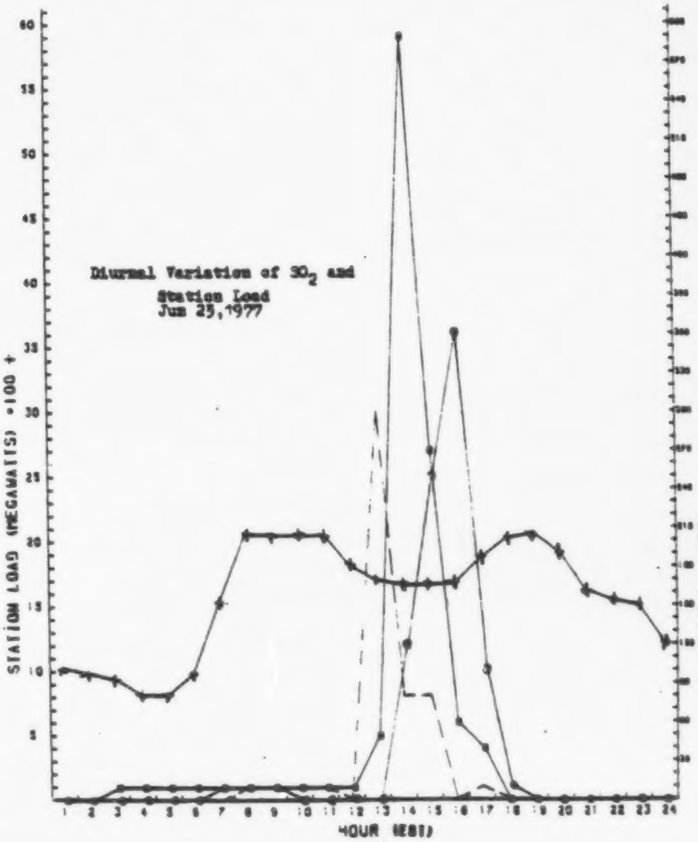
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 24 MAY 77



SO_2 EPISODE OF JUNE 23,1977



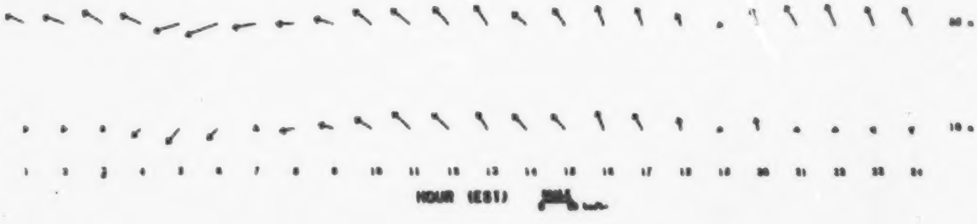
Surface Synoptic
Jun 23,1977



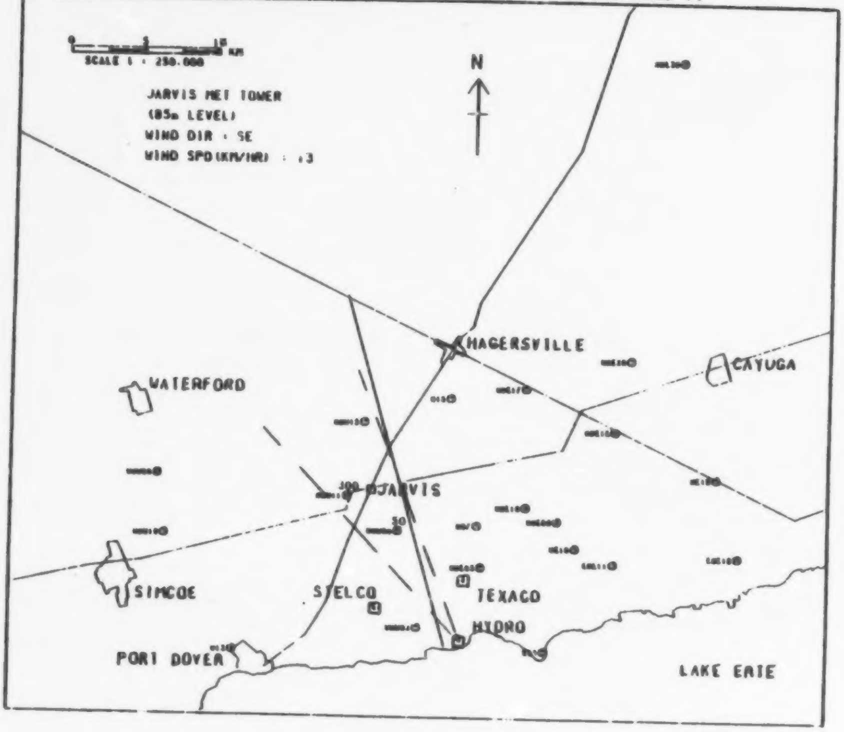
Diurnal Variation of SO_2 and
Station Load
Jun 23,1977

Wind Speed and Direction

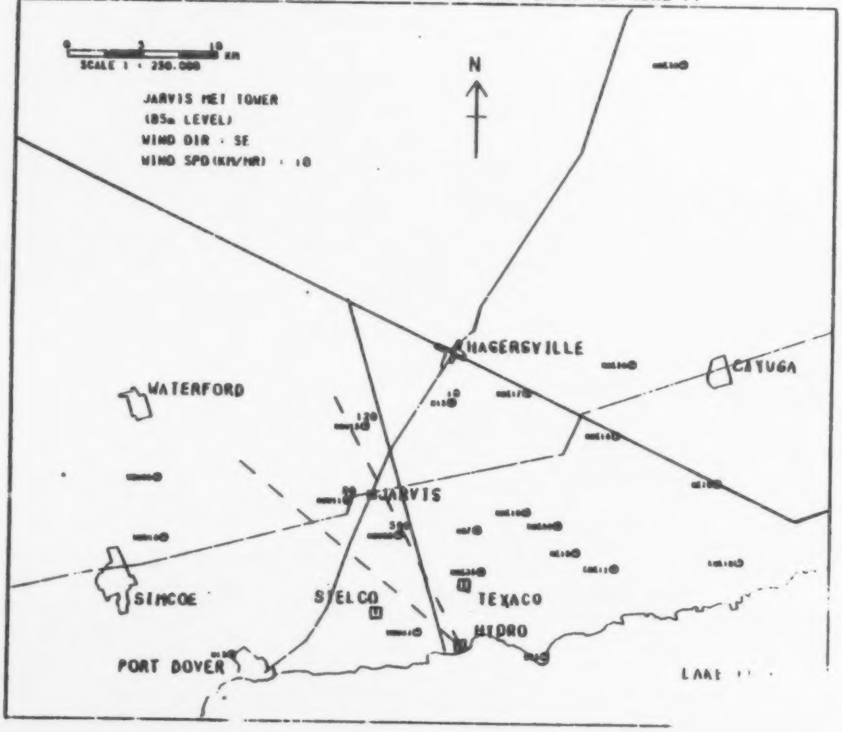
23 JUN 1977



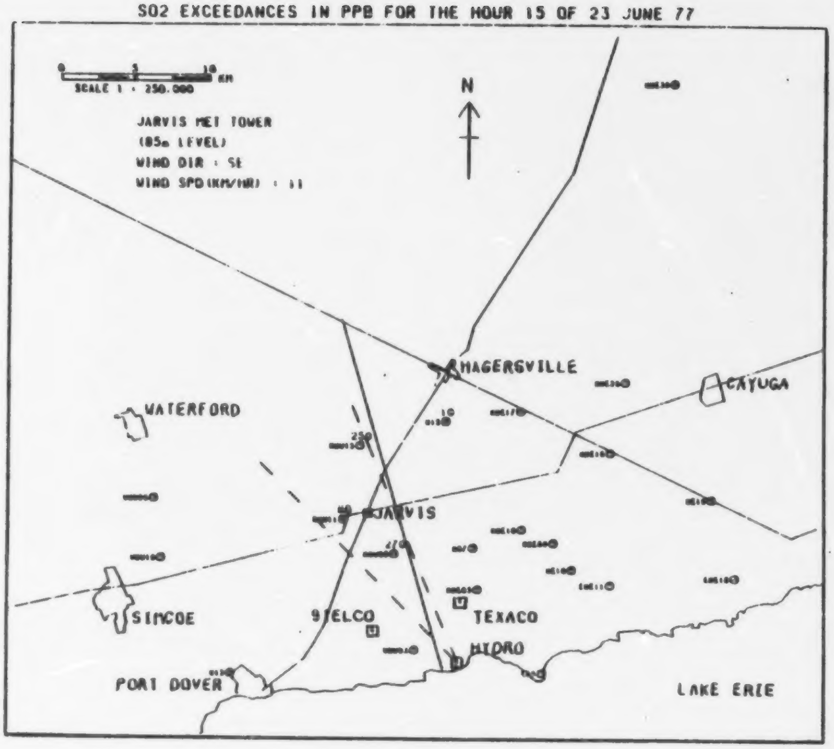
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 23 JUNE 77



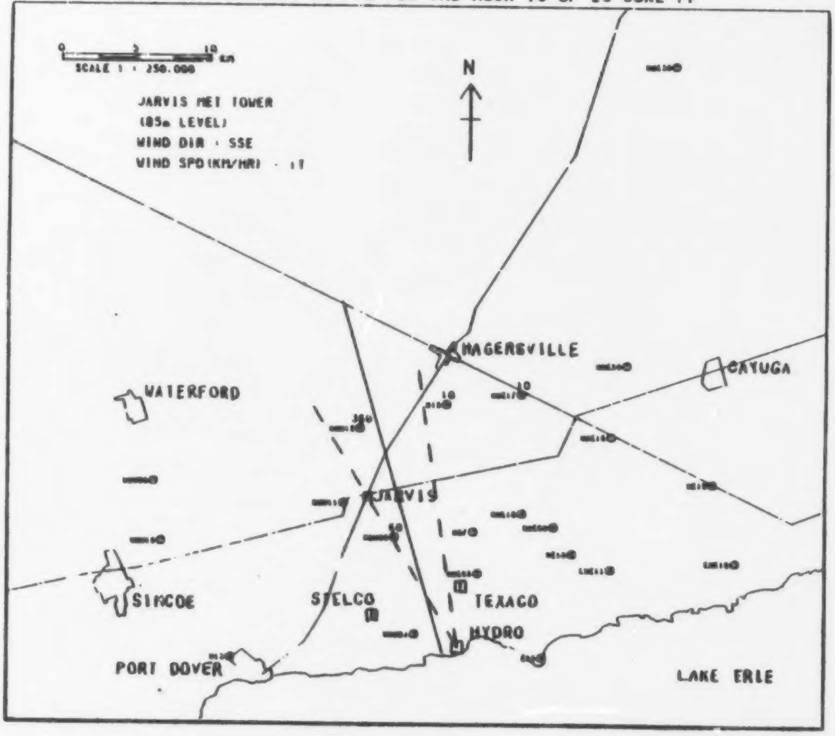
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 23 JUNE 77



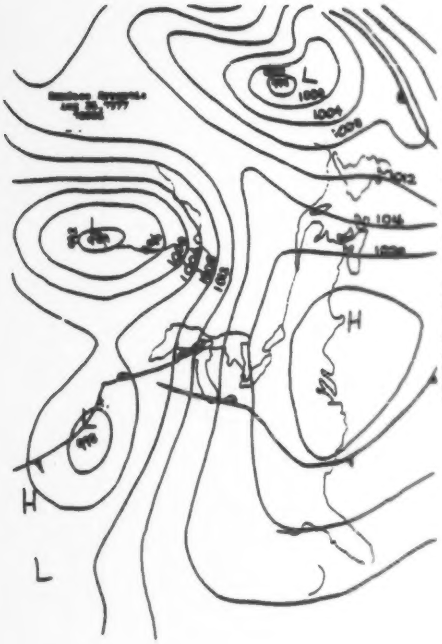
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 23 JUNE 77

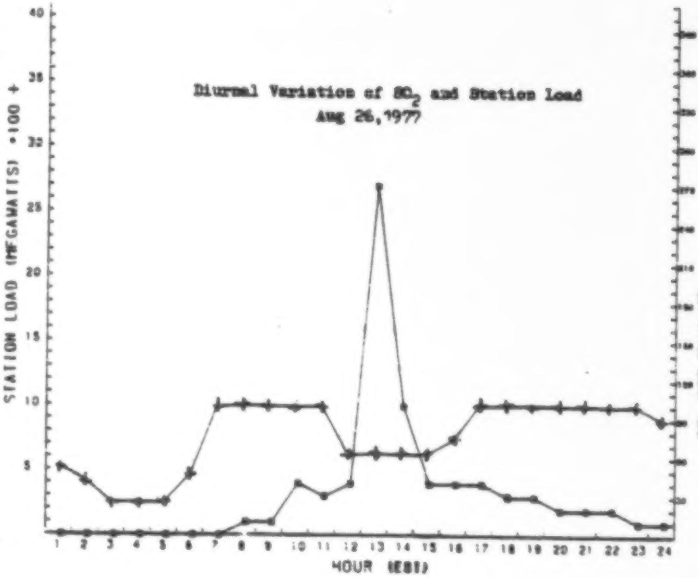


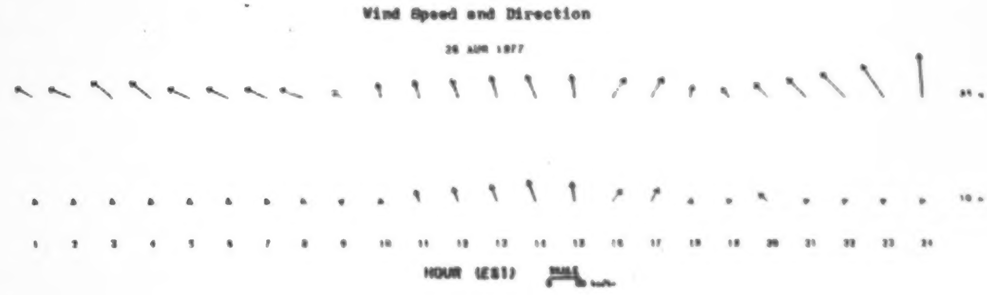
SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 23 JUNE 77



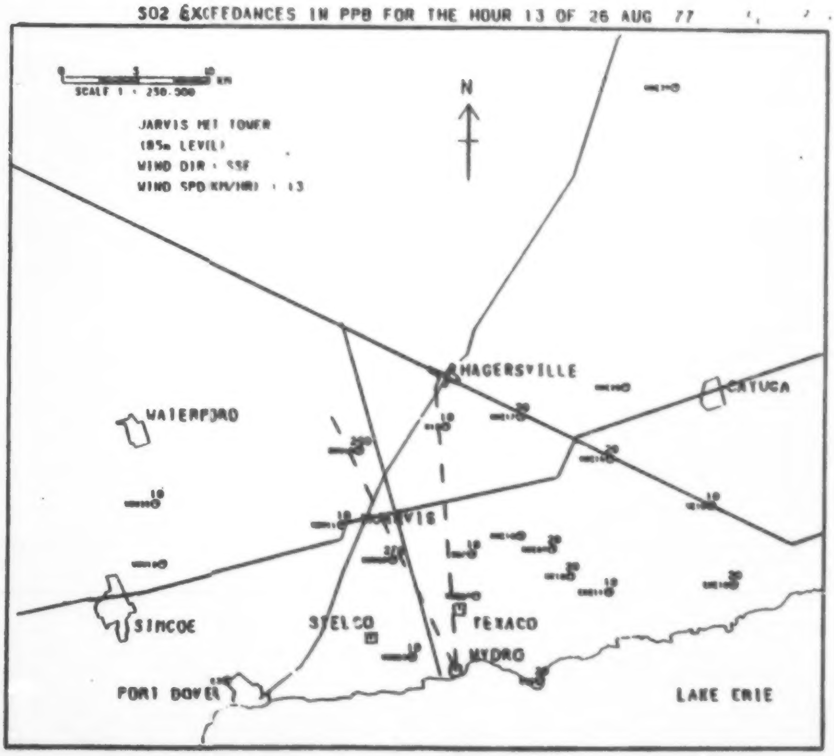
SO_2 EPISODE OF AUGUST 26,1977



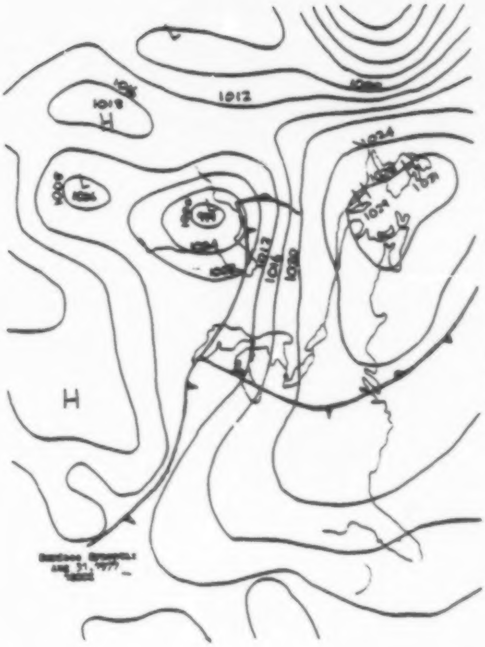


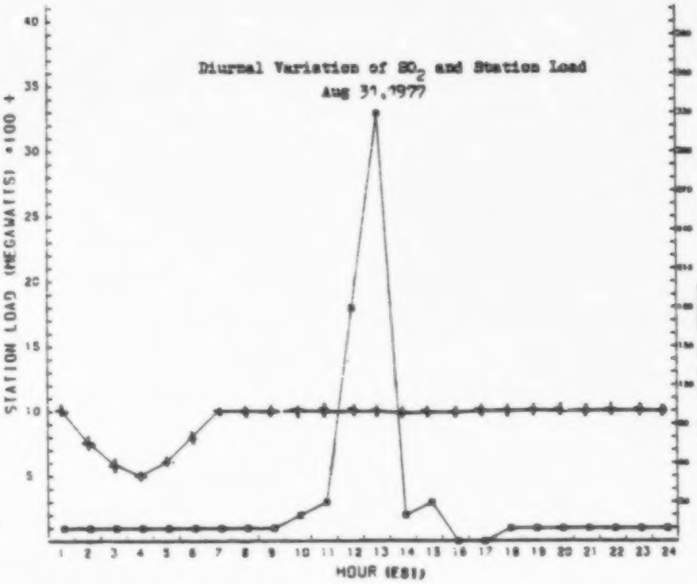


SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 26 AUG 77

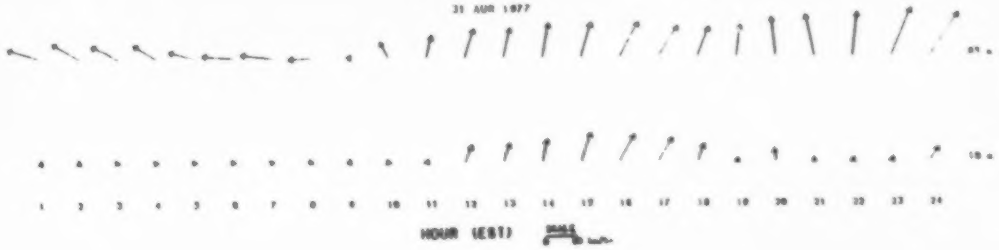


SO$_2$ EPISODE OF AUGUST 31,1977

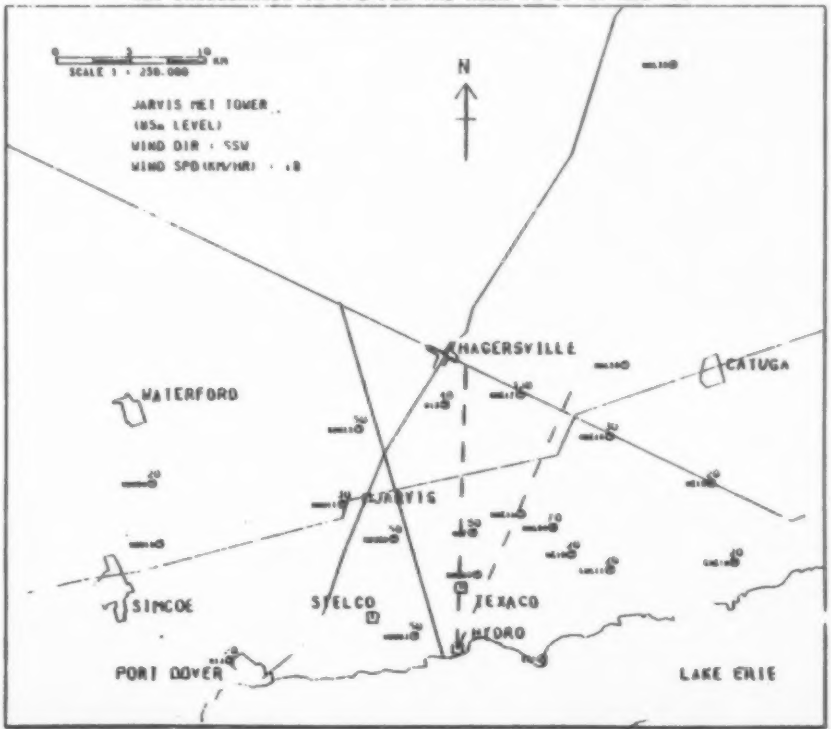




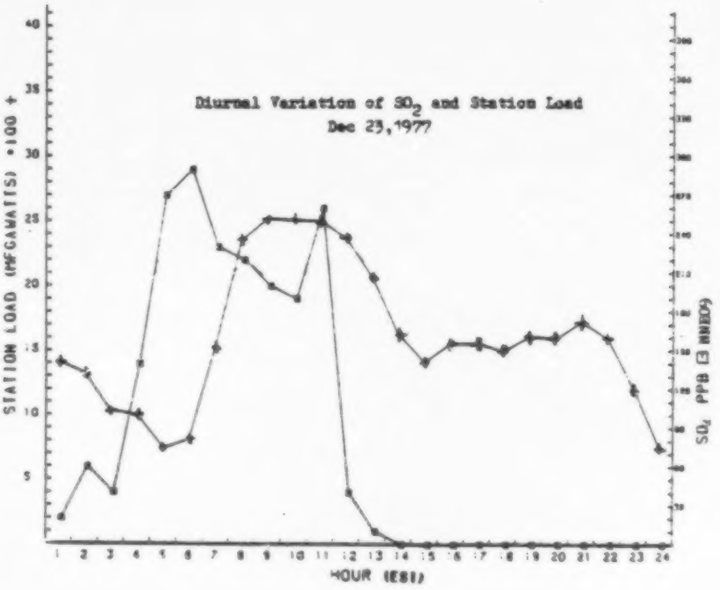
Wind Speed and Direction

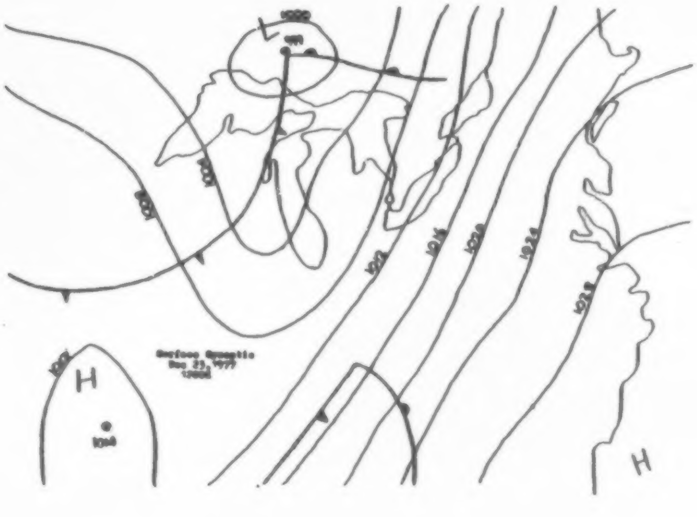


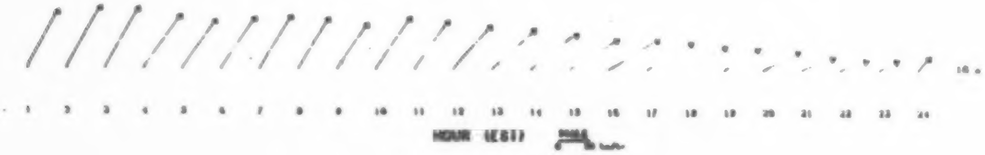
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 31 AUG 77



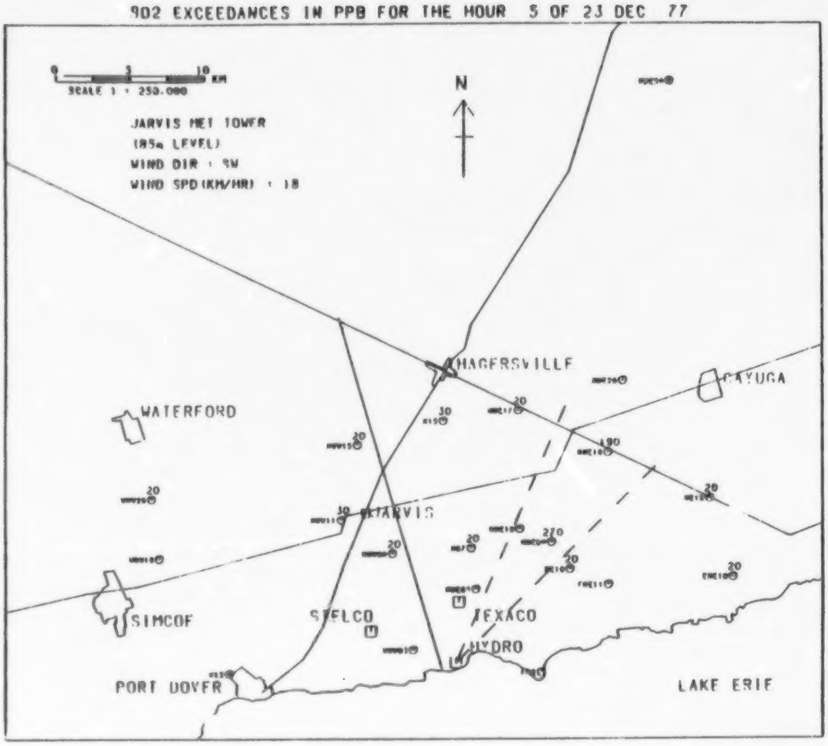
SO_2 EPISODE OF DECEMBER 23,1977



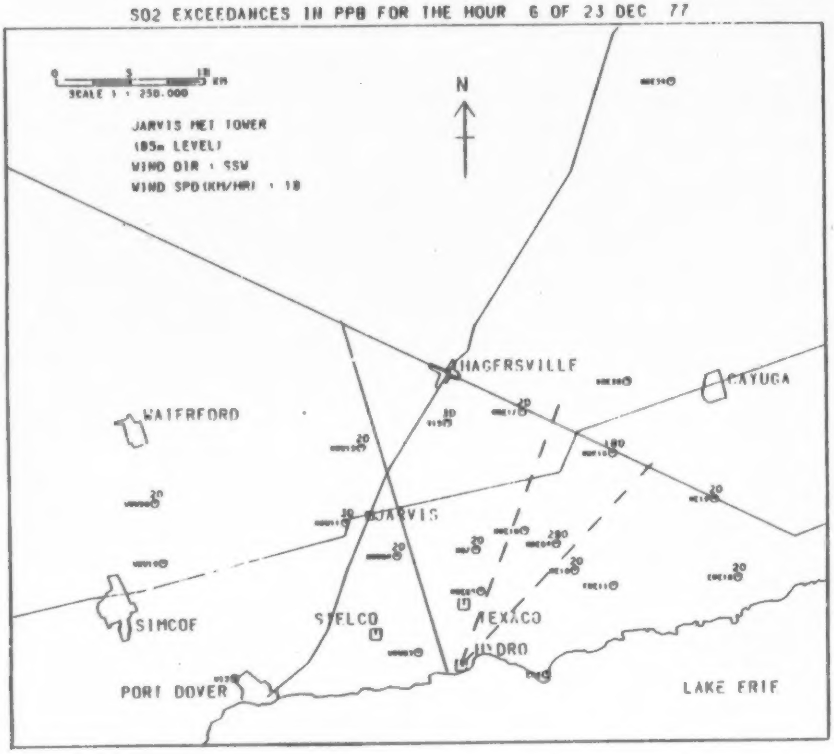




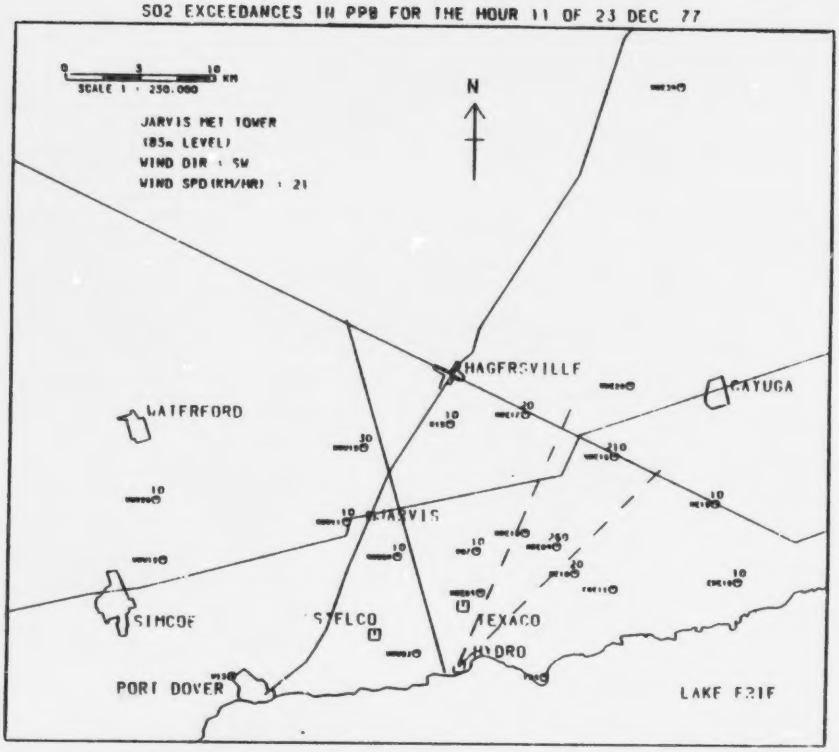
SO2 EXCEEDANCES IN PPB FOR THE HOUR 5 OF 23 DEC 77



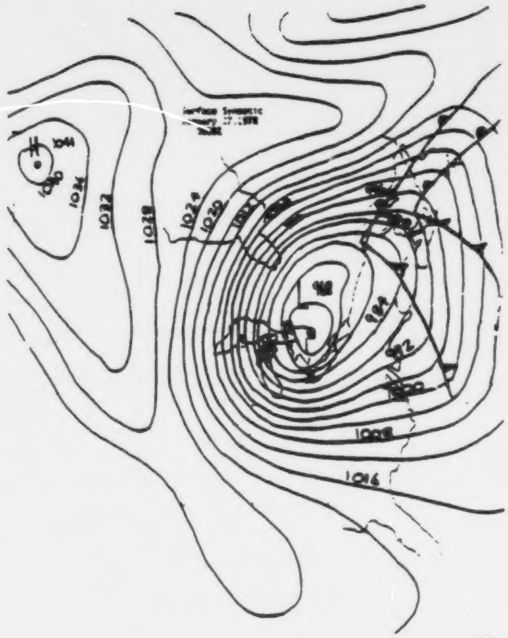
SO2 EXCEEDANCES IN PPB FOR THE HOUR 6 OF 23 DEC 77

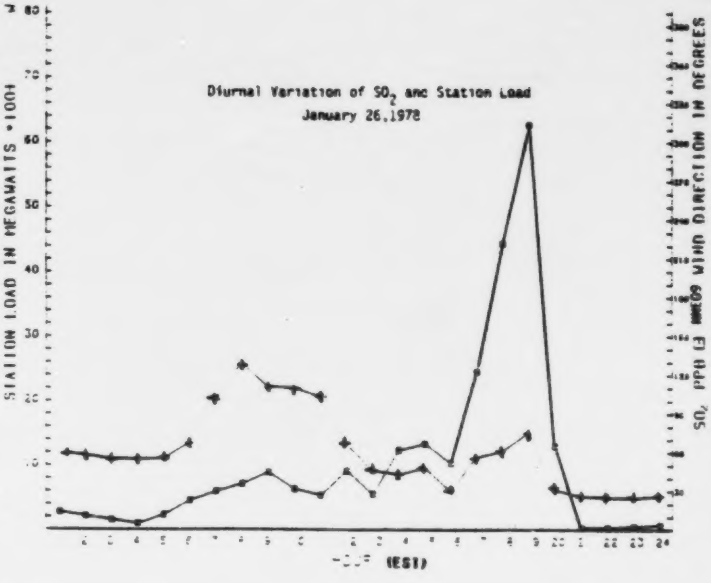


SO2 EXCEEDANCES IN PPB FOR THE HOUR 11 OF 23 DEC 77



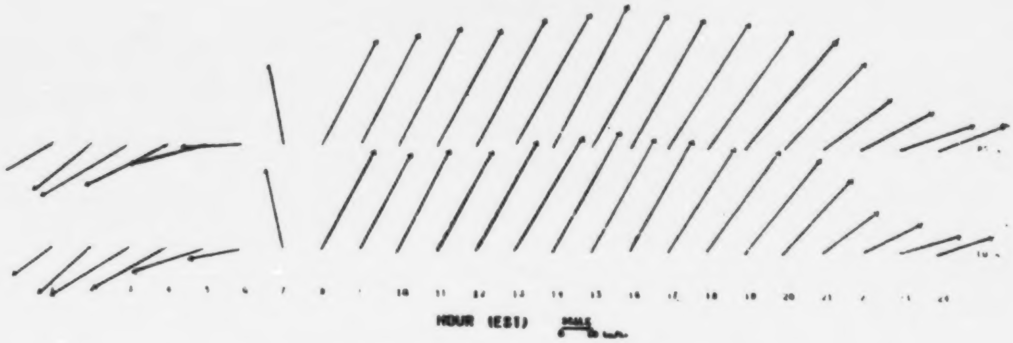
SO$_2$ EPISODE OF JANUARY 26,1978



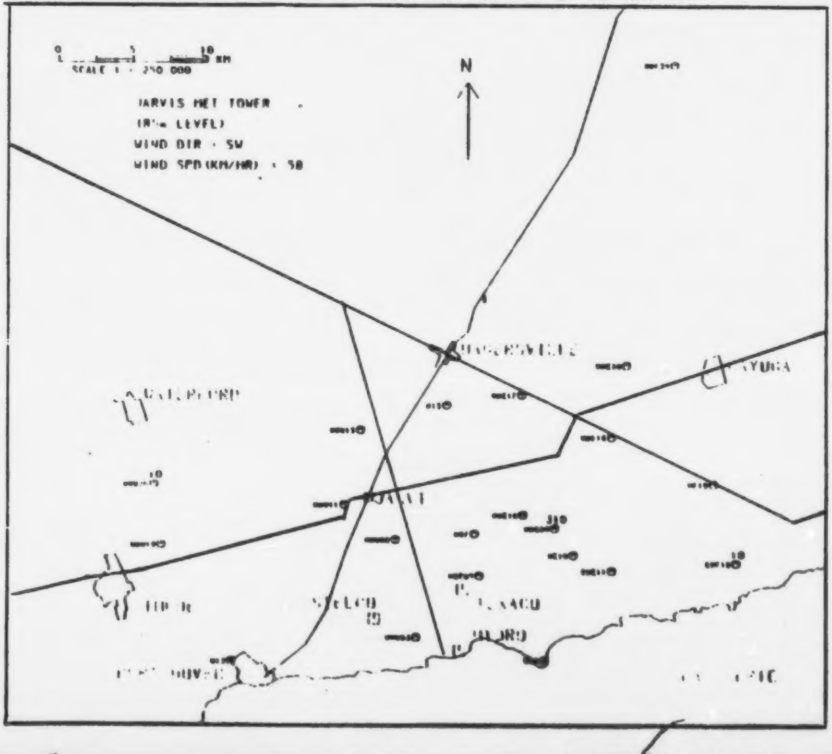


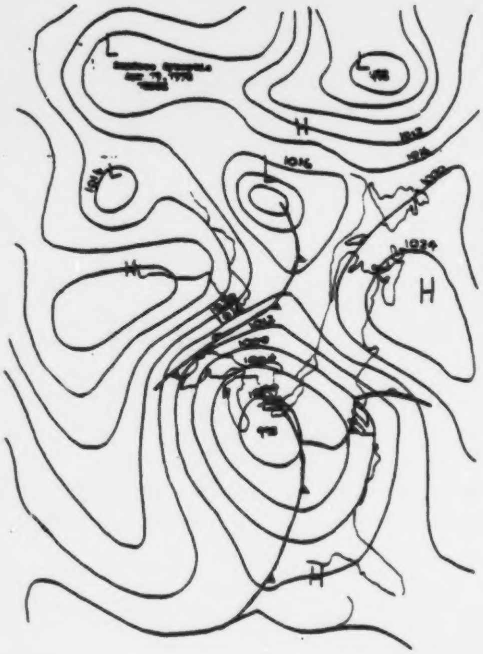
Wind Speed and Direction

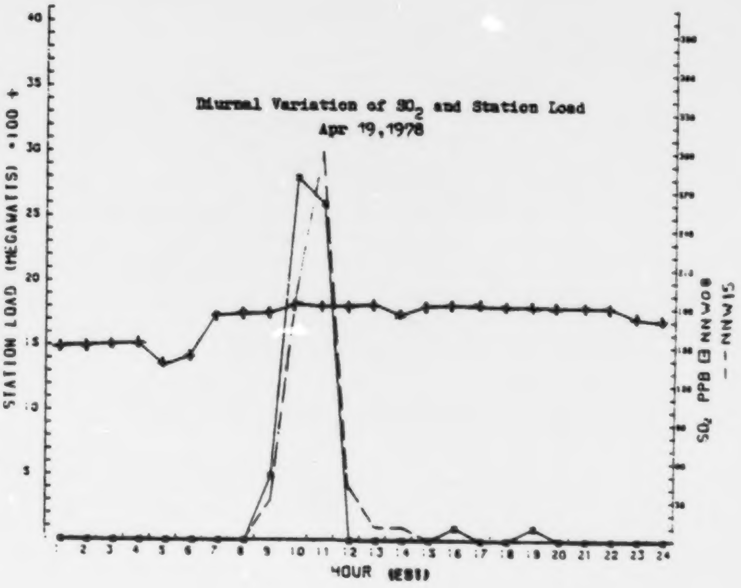
26 JAN 1978

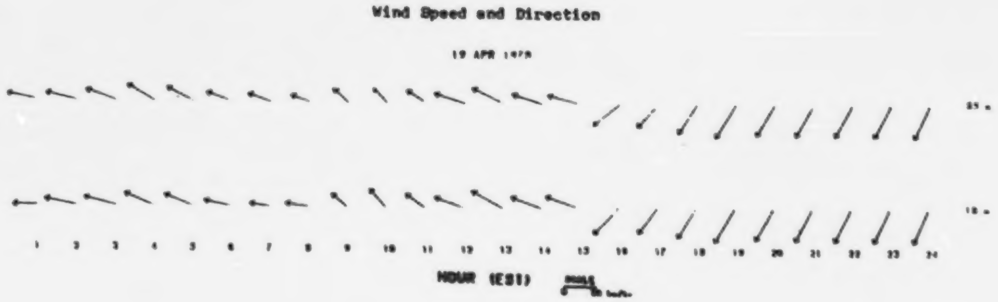


SO2 EXCEEDANCES IN PPB FOR THE HOUR 19 OF 26 JAN 78

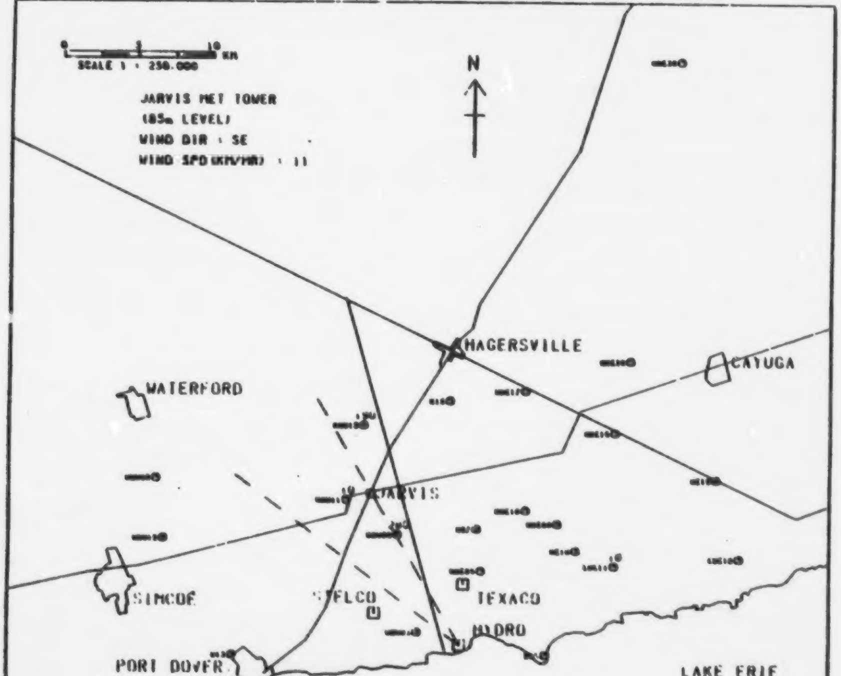




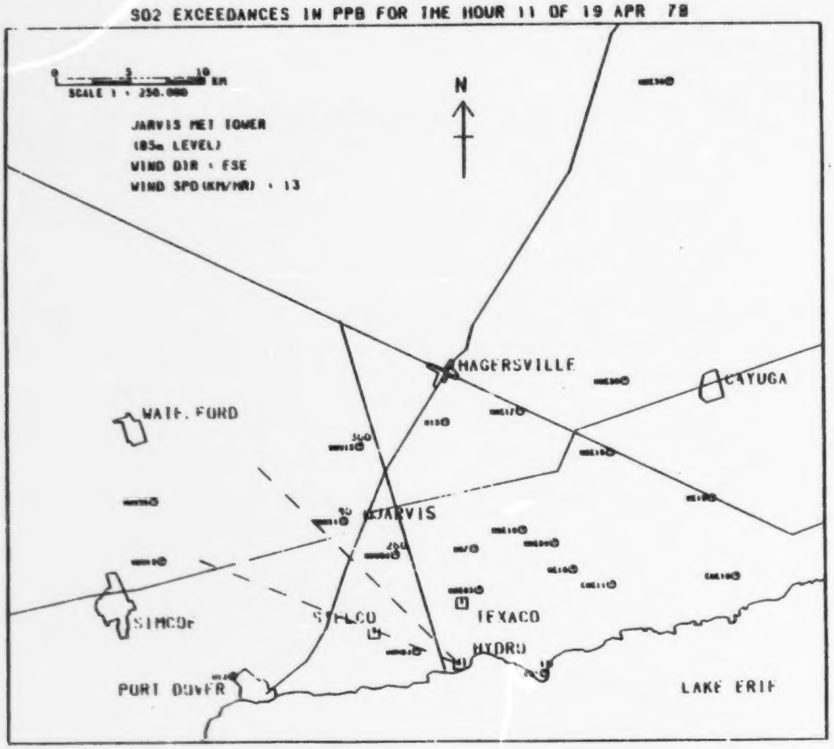




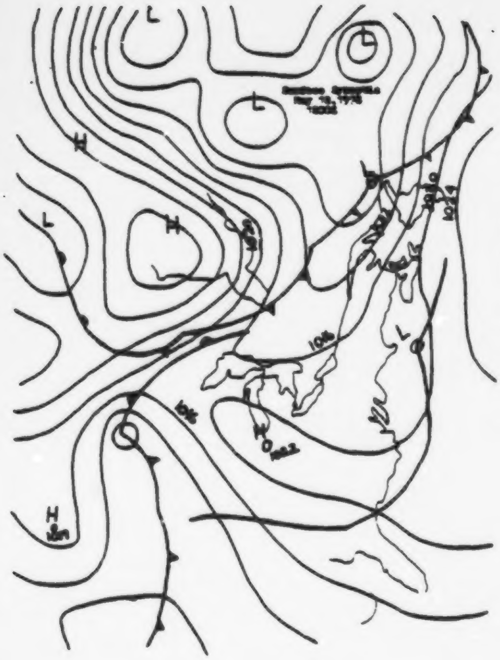
SO2 EXCEEDANCES IN PPB FOR THE HOUR 10 OF 19 APR 78

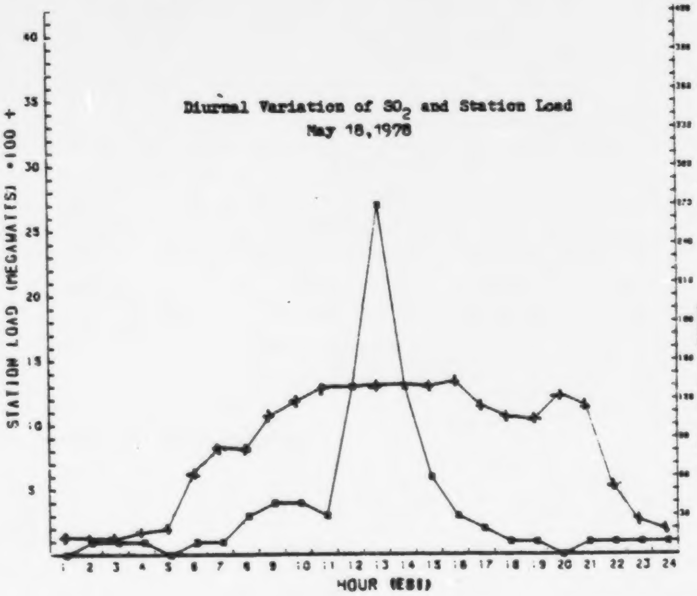


SO2 EXCEEDANCES IN PPB FOR THE HOUR 11 OF 19 APR 78

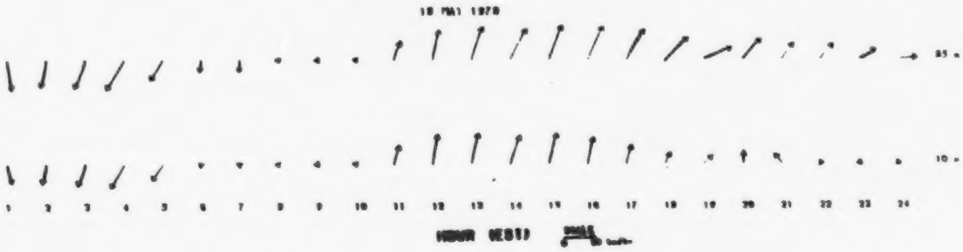


SO_2 EPISODE OF MAY 18,1973





Wind Speed and Direction



SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 18 MAY 78

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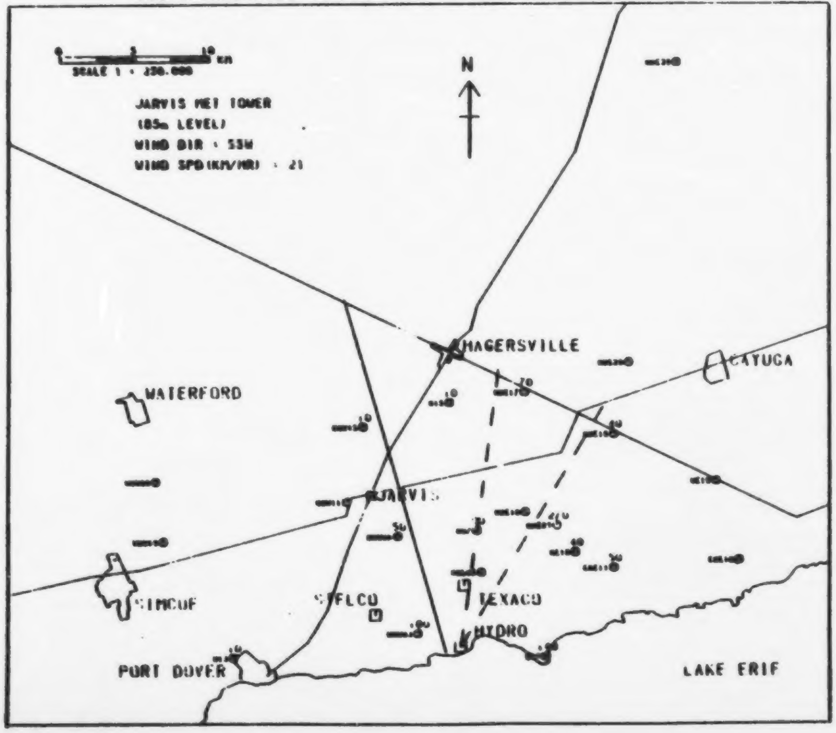
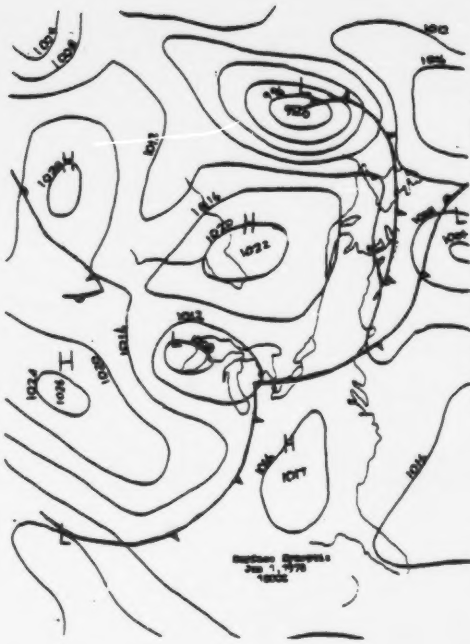
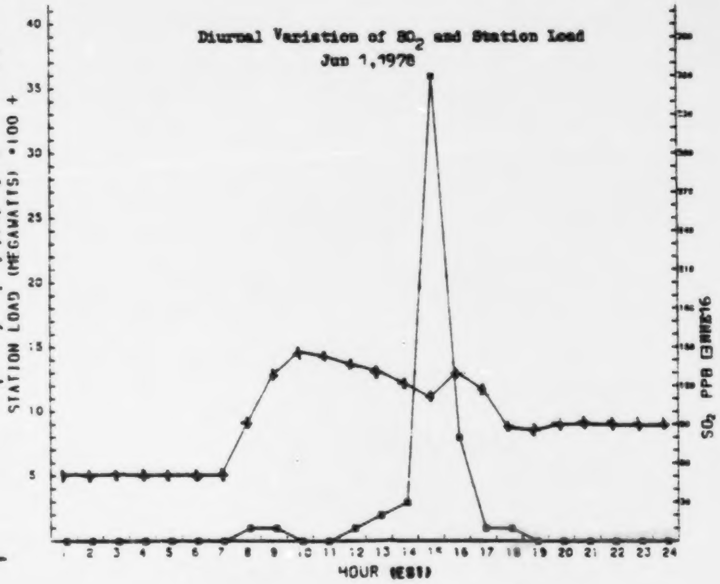
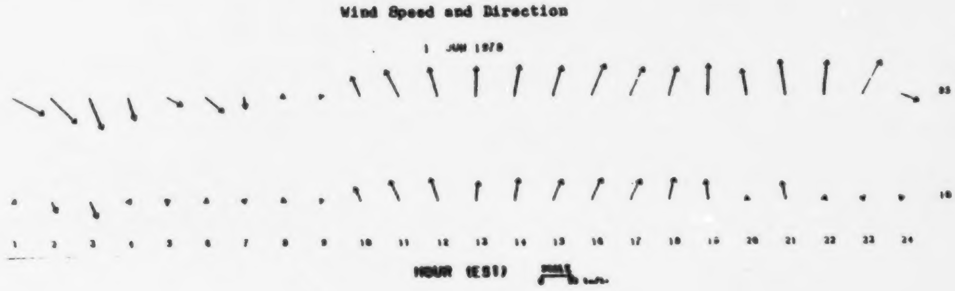
LBI ·A



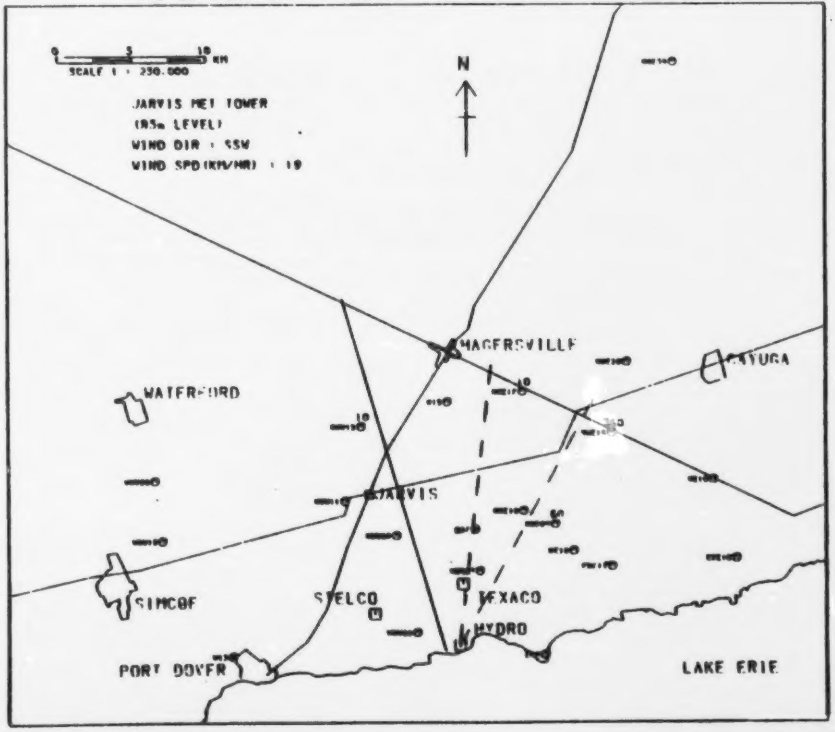
SO_2 EPISODE OF JUNE 1,1978



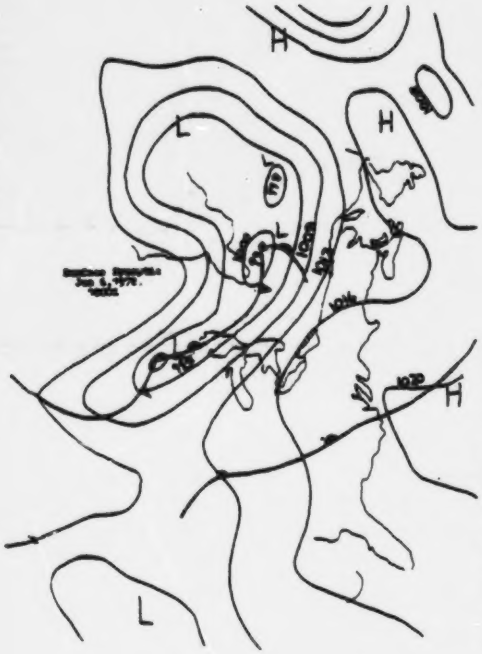


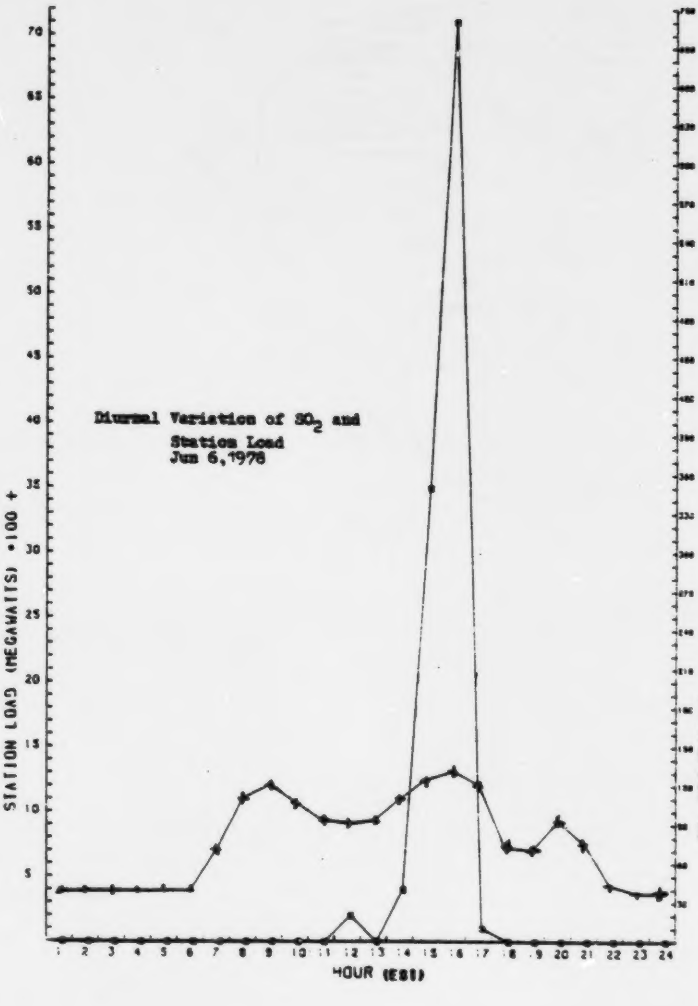


SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 1 JUNE 78



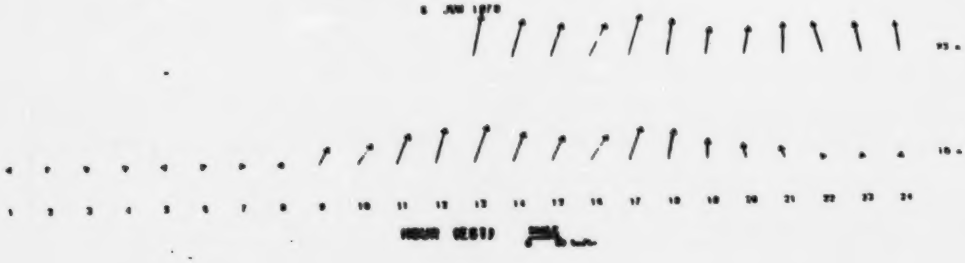
SO_2 EPISODE JUNE 6,1973



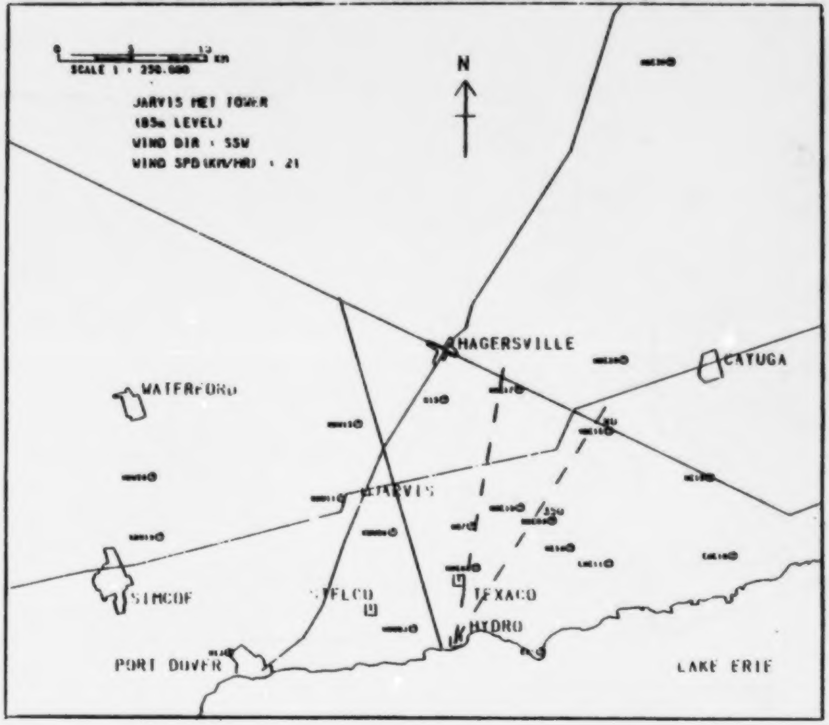


Diurnal Variation of SO_2 and Station Load Jun 6,1978

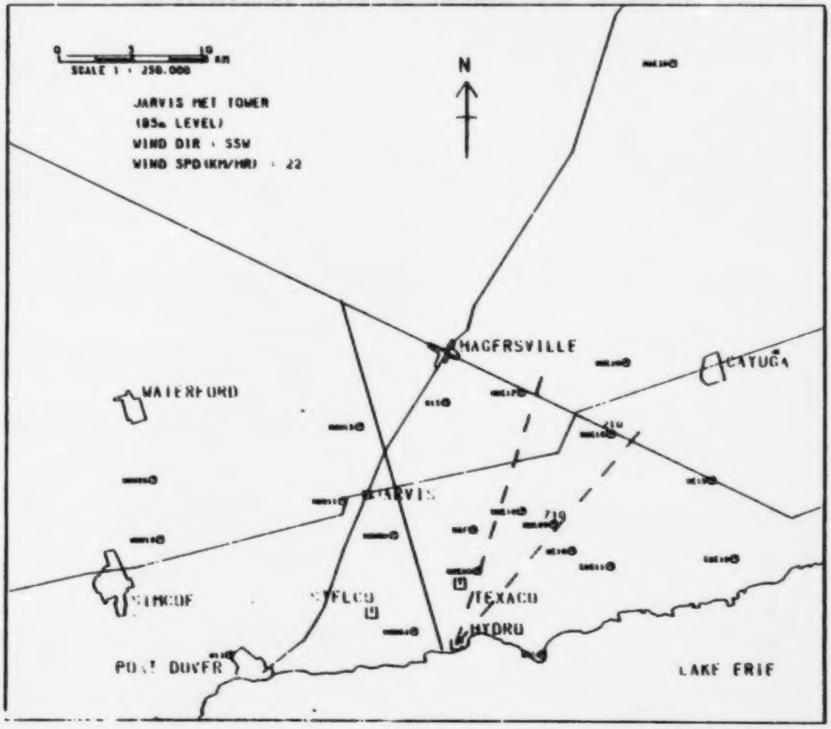
Wind Speed and Direction

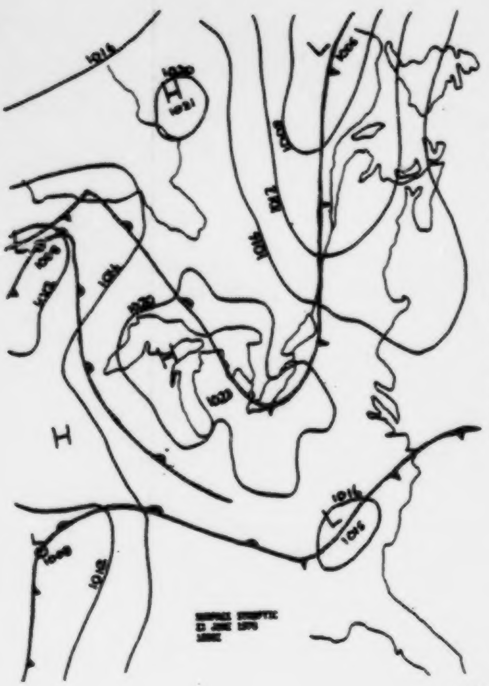


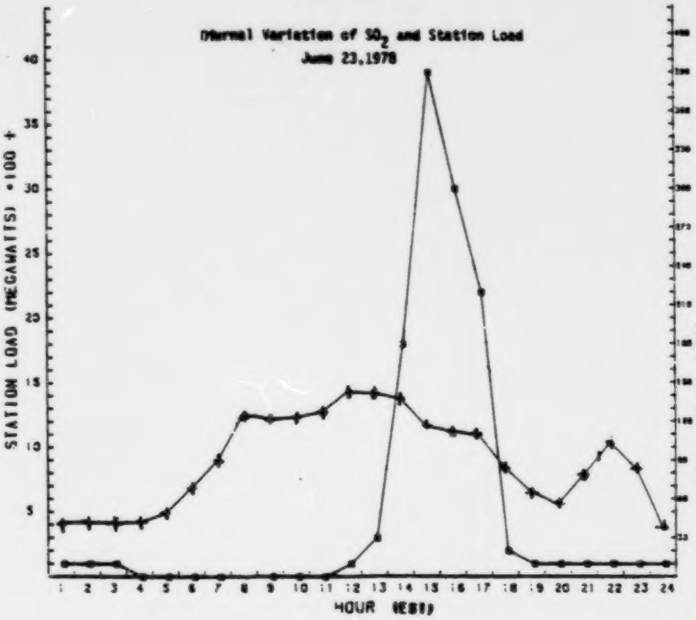
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 6 JUNE 78



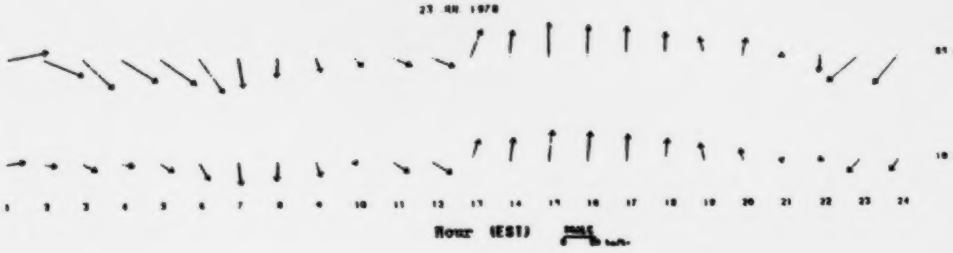
SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 6 JUNE 78



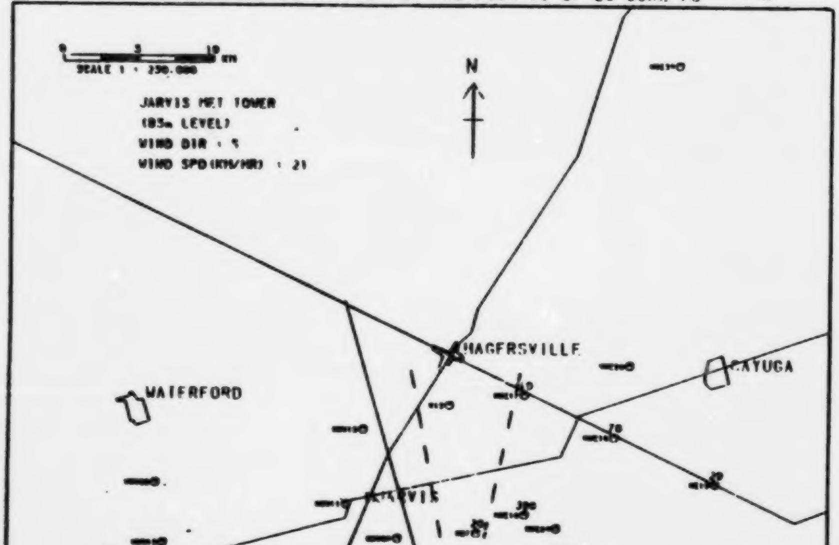




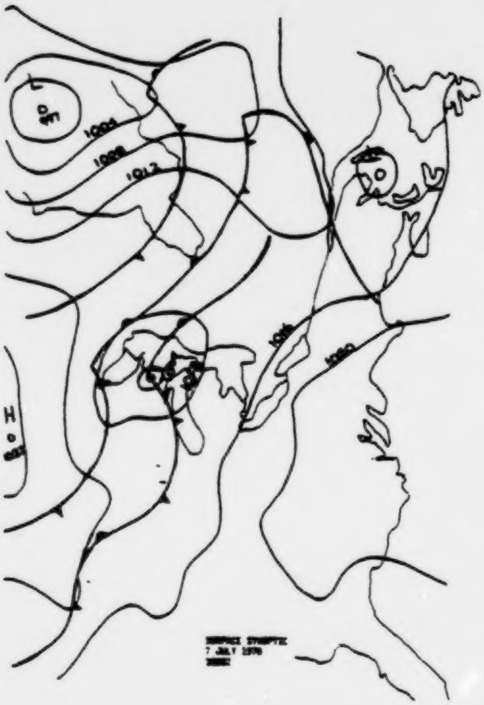
Wind Speed and Direction

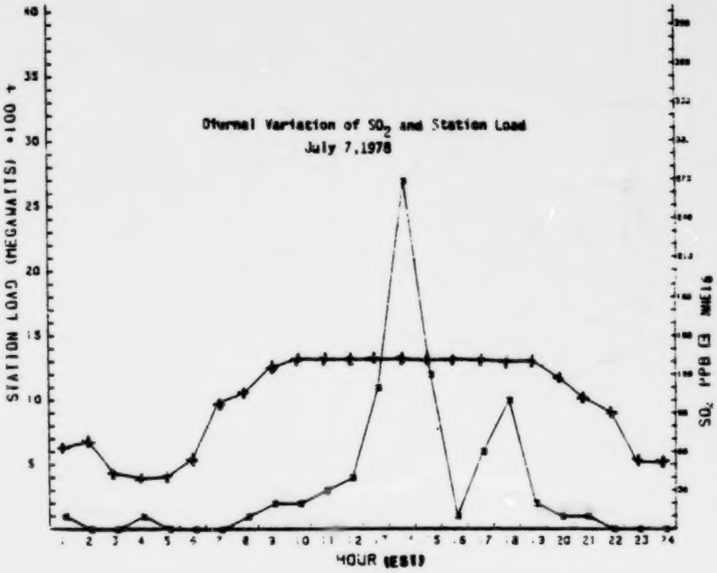


SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 23 JUNE 78

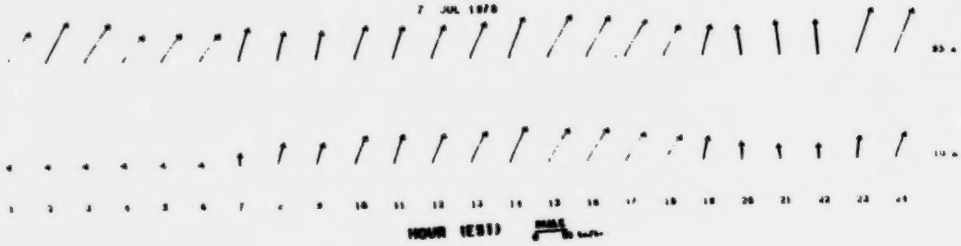


SO$_2$ EPISODE OF JULY 7,1978

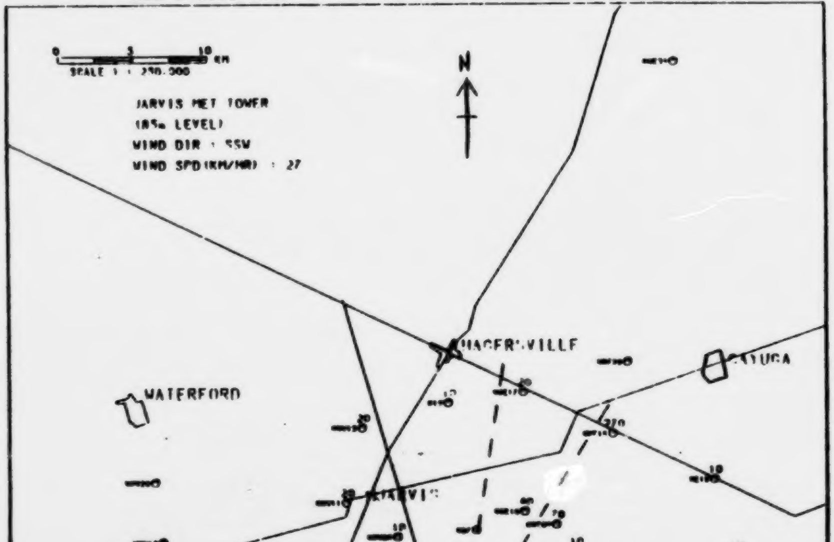




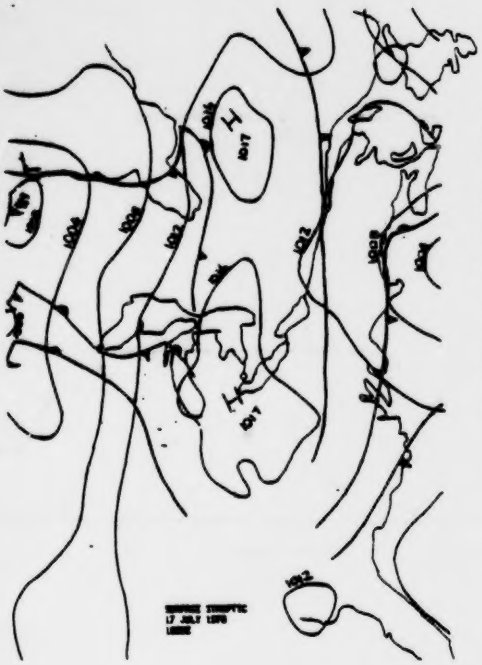
Wind Speed and Direction

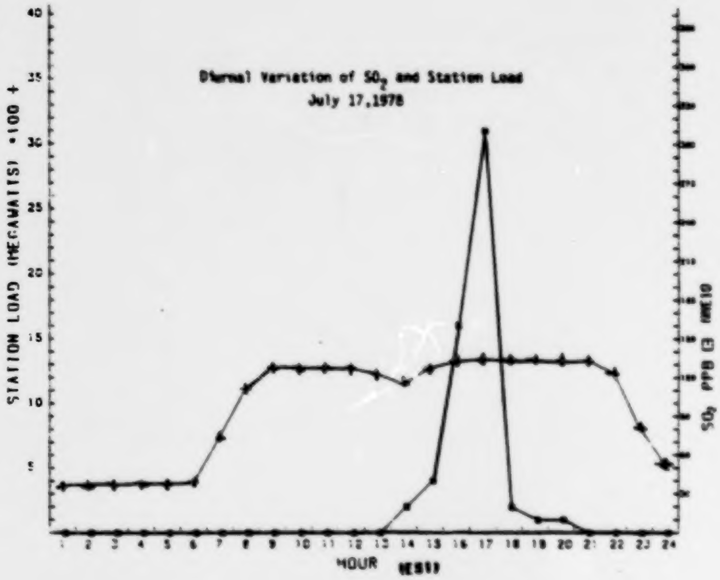


SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 7 JULY 78



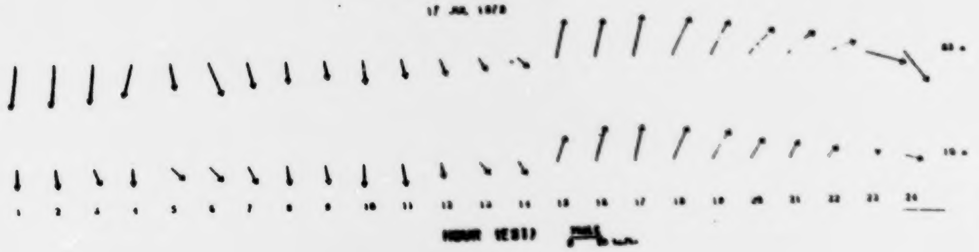
SO_2 EPISODE OF JULY 17,1978



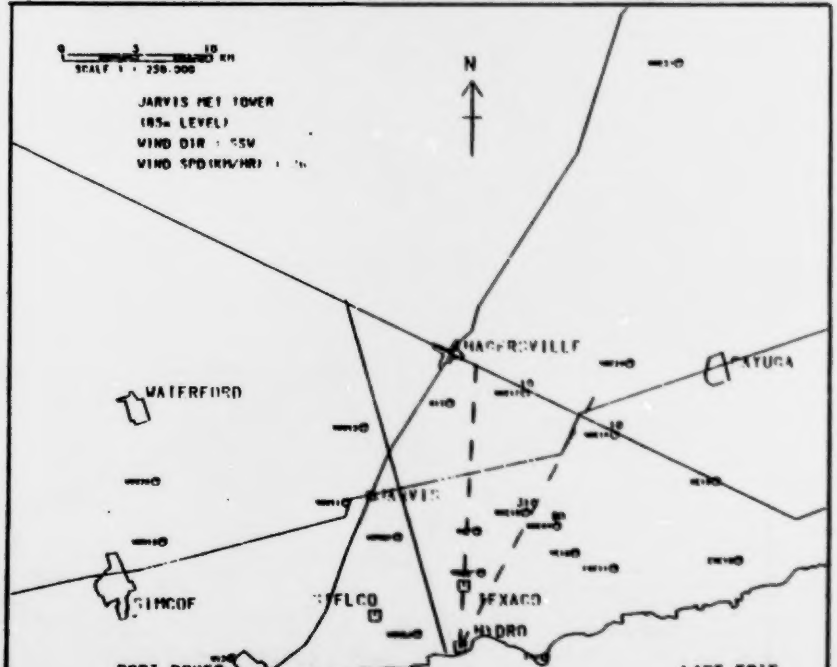


Wind Speed and Direction

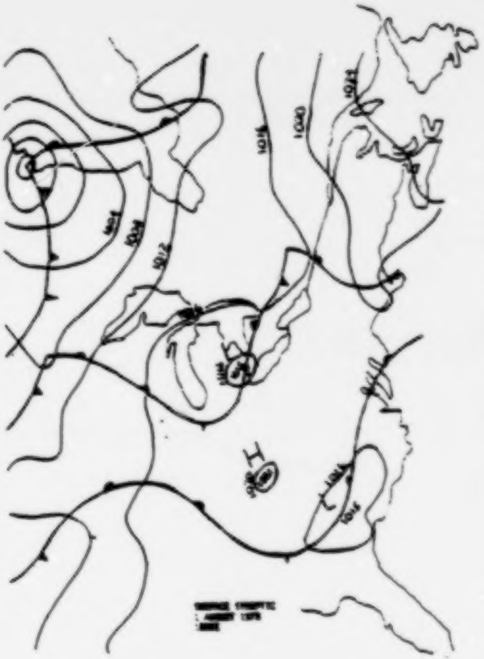
17 JUL 1978

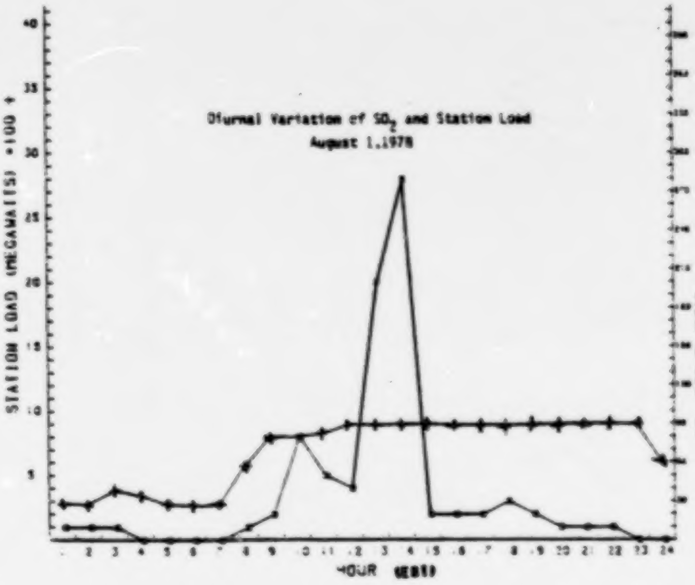


SO2 EXCEEDANCES IN PPB FOR THE HOUR 17 OF 17 JULY 78

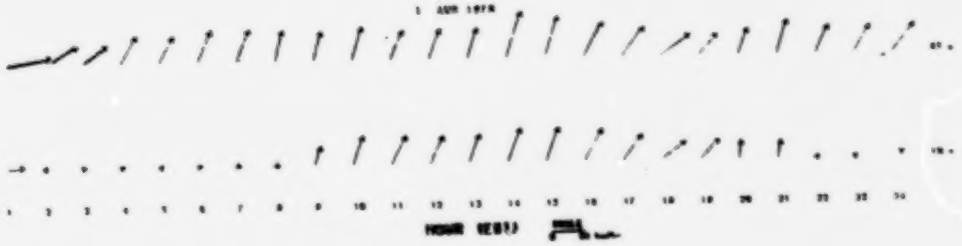


SO$_2$ EPISODE OF AUGUST 1,1978

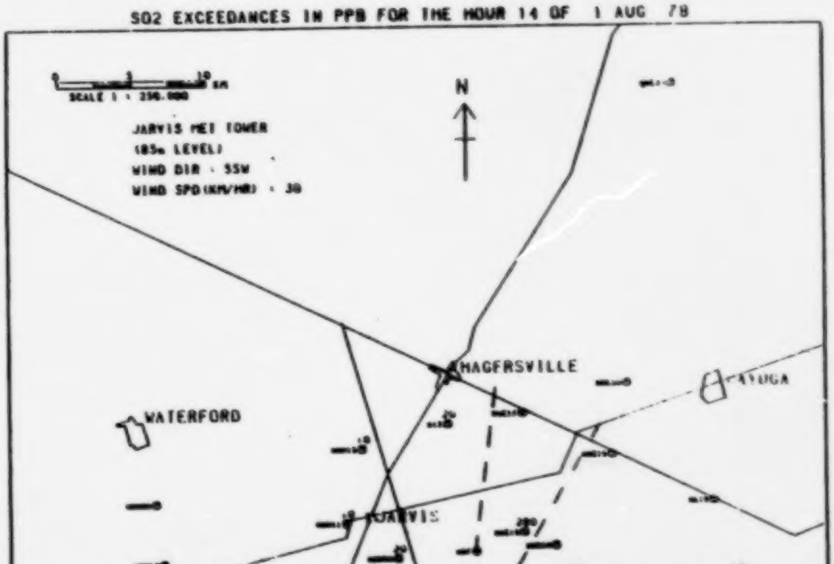




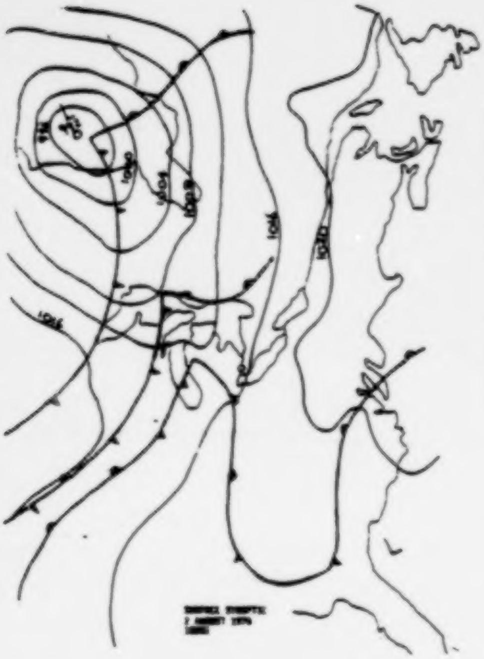
Wind Speed and Direction

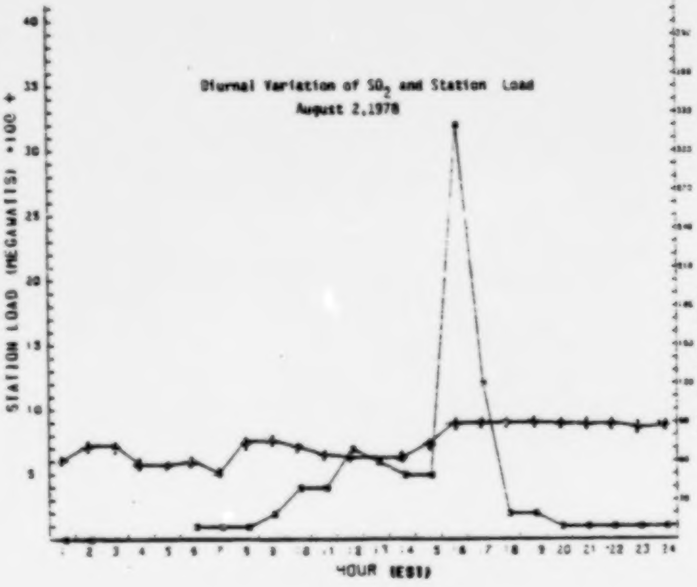


SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 1 AUG 78

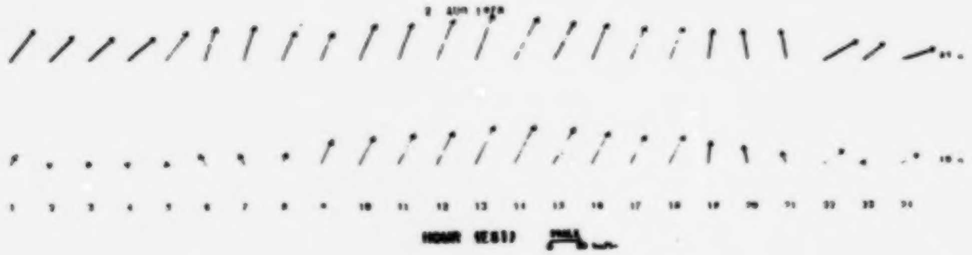


SO_2 EPISODE OF AUGUST 2,1978

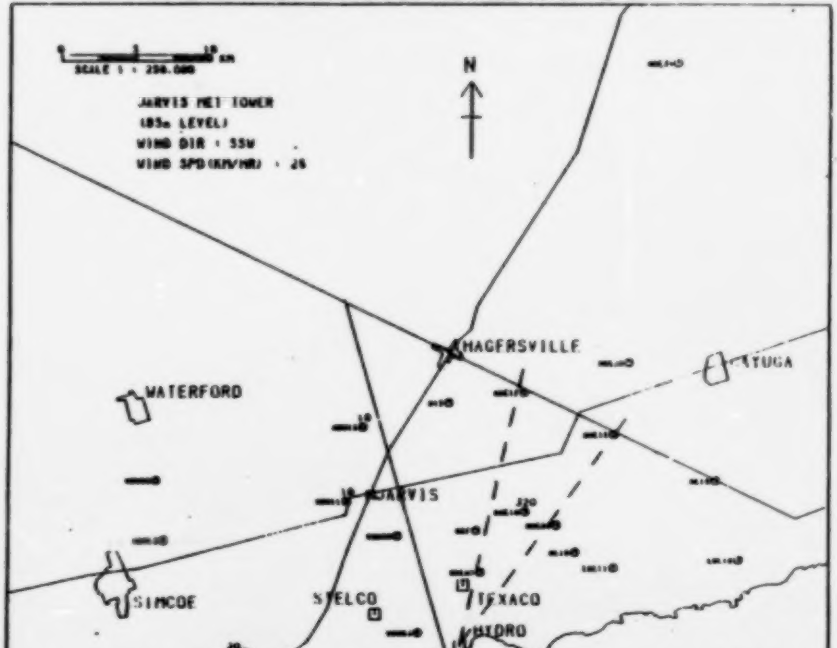




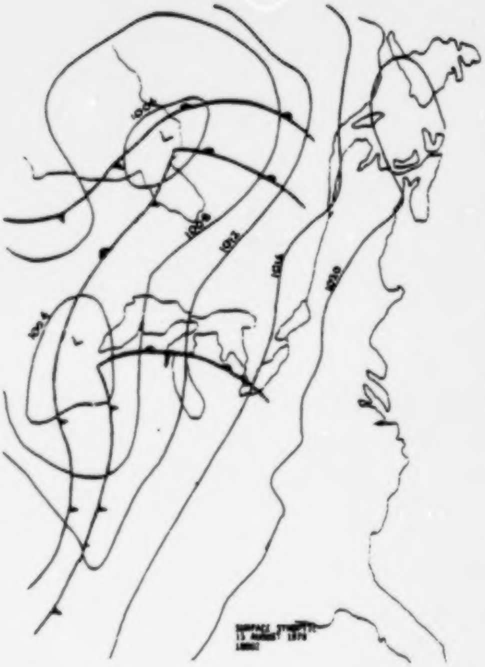
Wind Speed and Direction

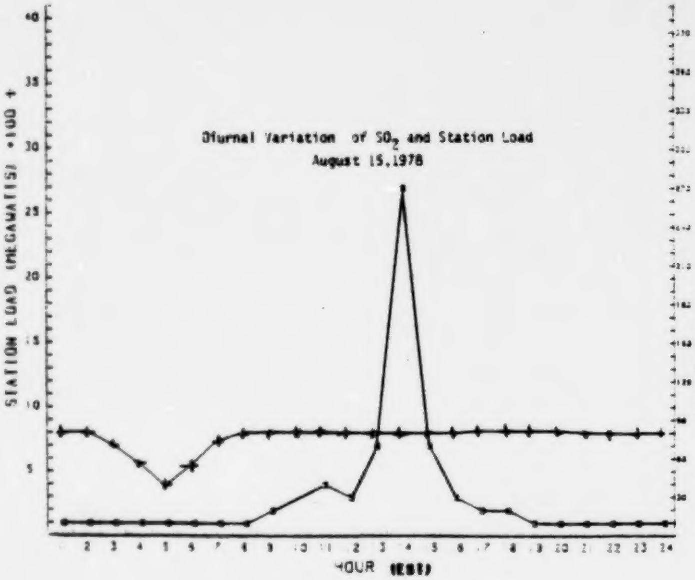


SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 2 AUG 78

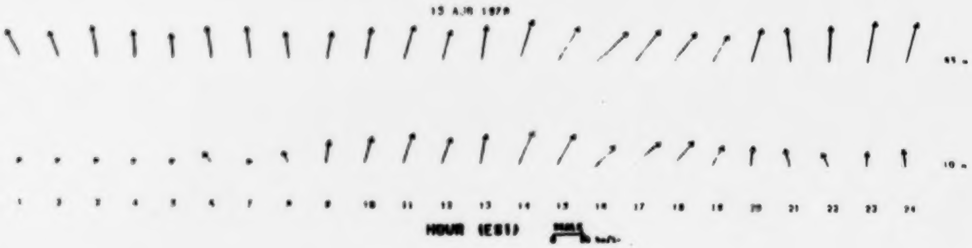


SO$_2$ EPISODE OF AUGUST 15,1978

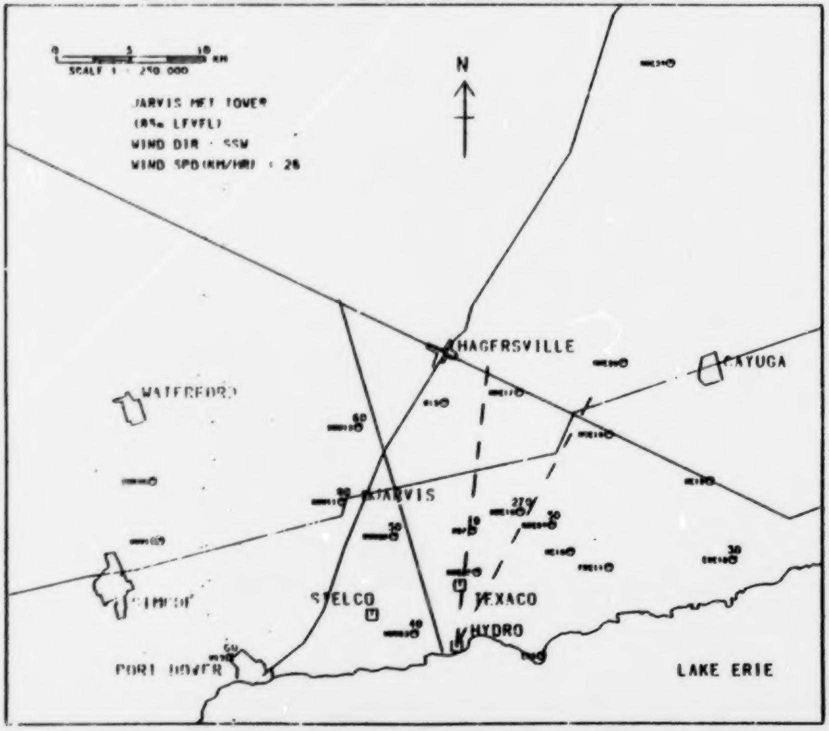




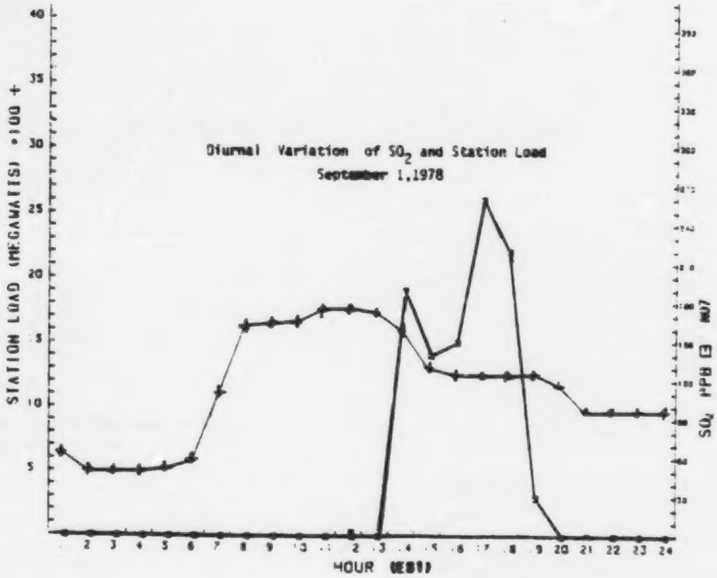
Wind Speed and Direction

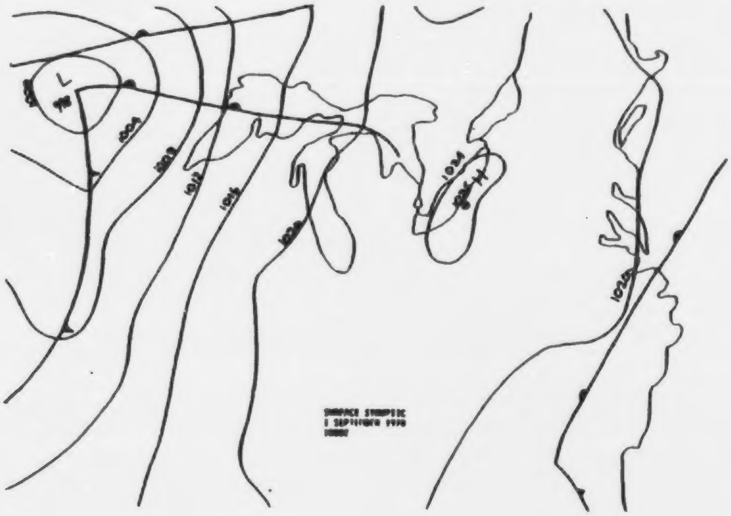


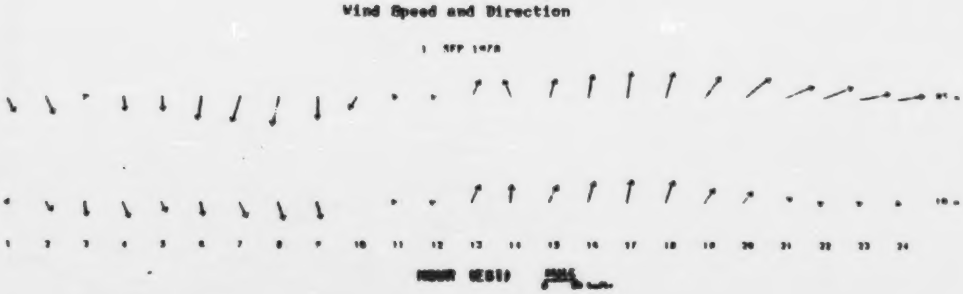
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 15 AUG 78



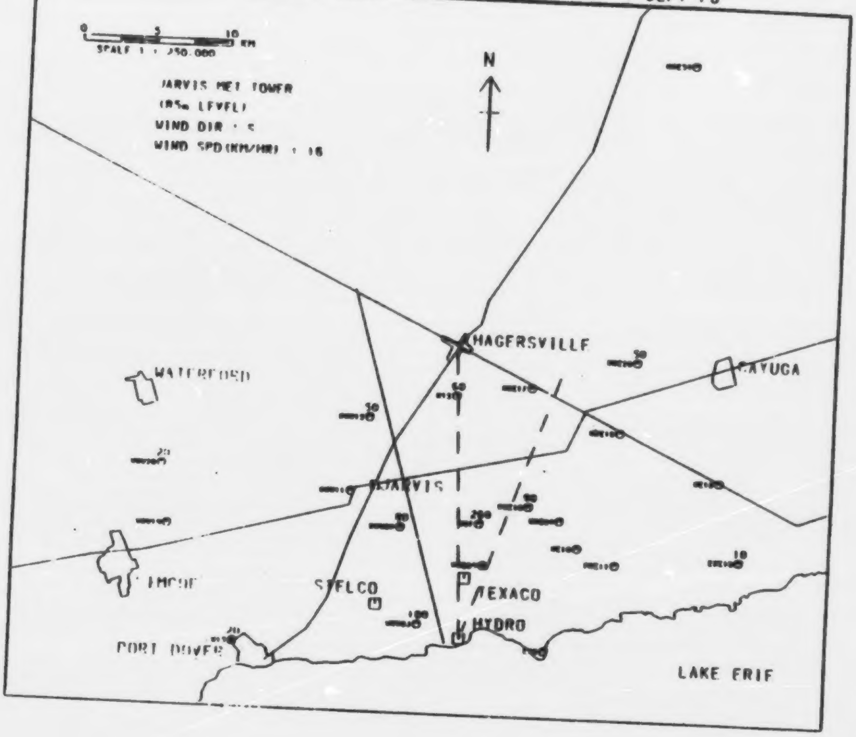
SO_2 EPISODE OF SEPTEMBER 1,1978



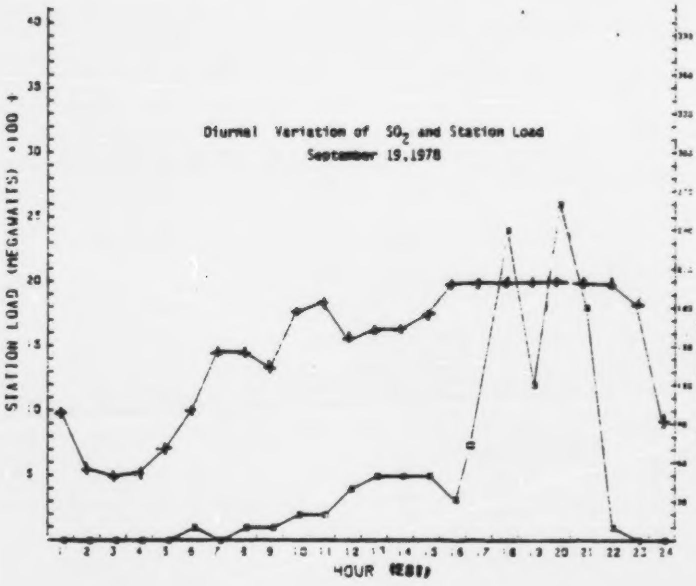


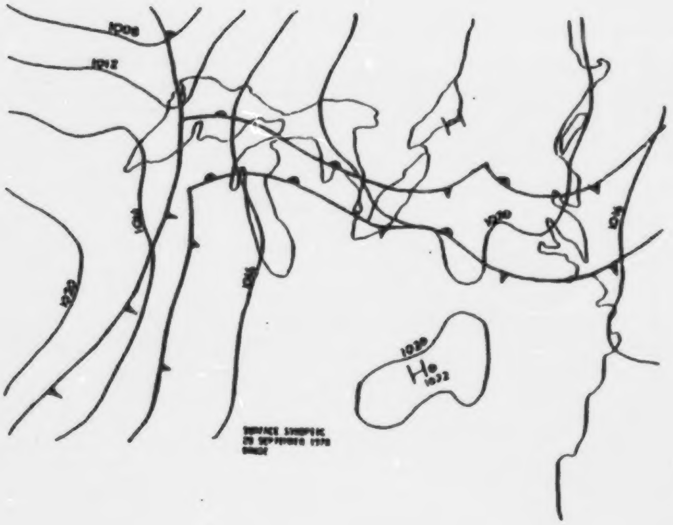


SO2 EXCEEDANCES IN PPB FOR THE HOUR 17 OF 1 SEPT 78



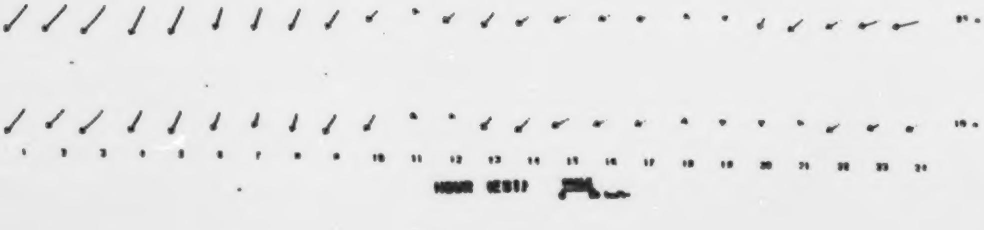
SO_2 EPISODE OF SEPTEMBER 19,1978



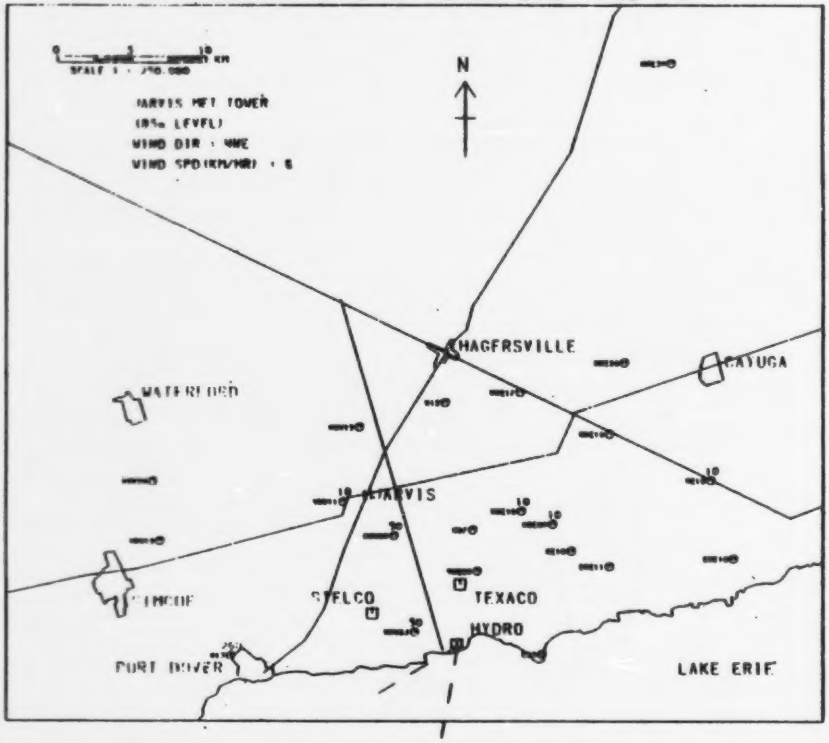


Wind Speed and Direction

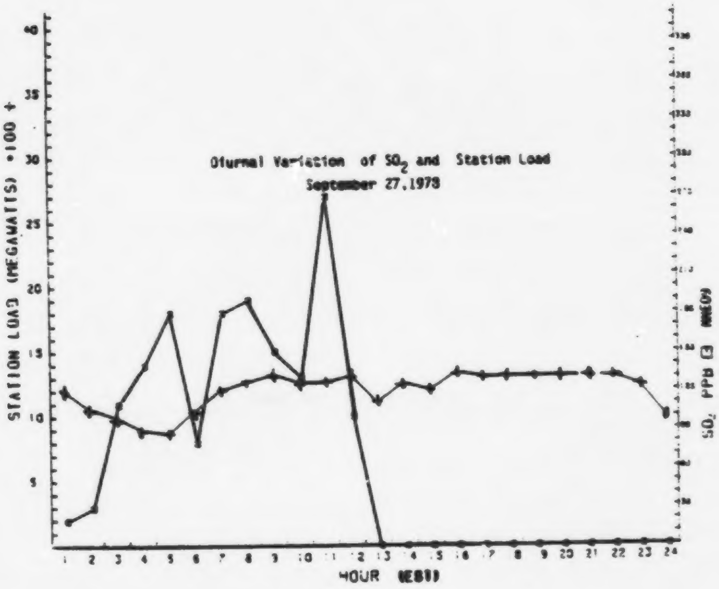
19 SEP 1978

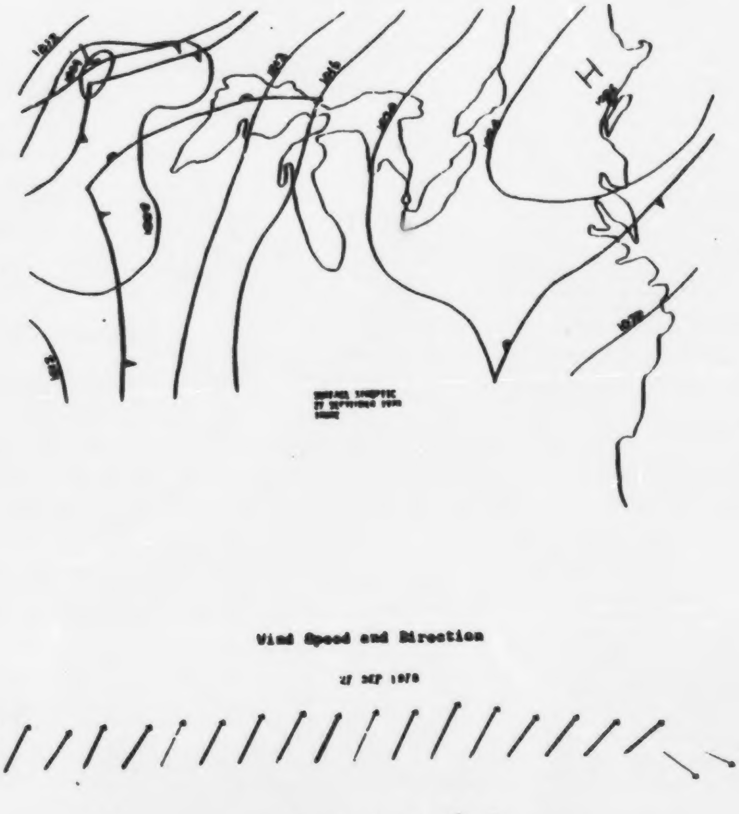


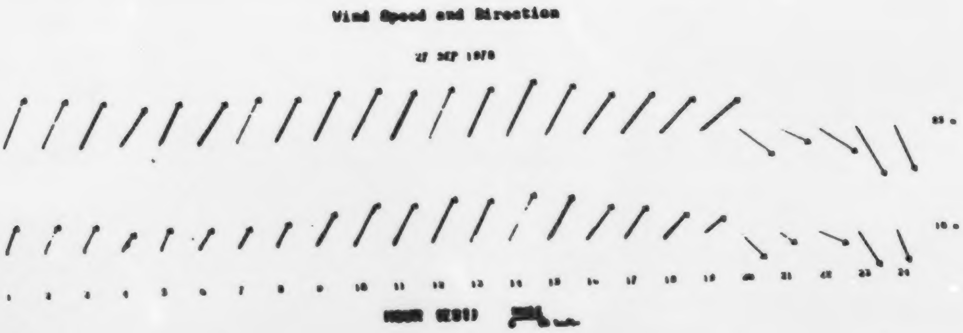
SO2 EXCEEDANCES IN PPB FOR THE HOUR 20 OF 19 SEPT 78



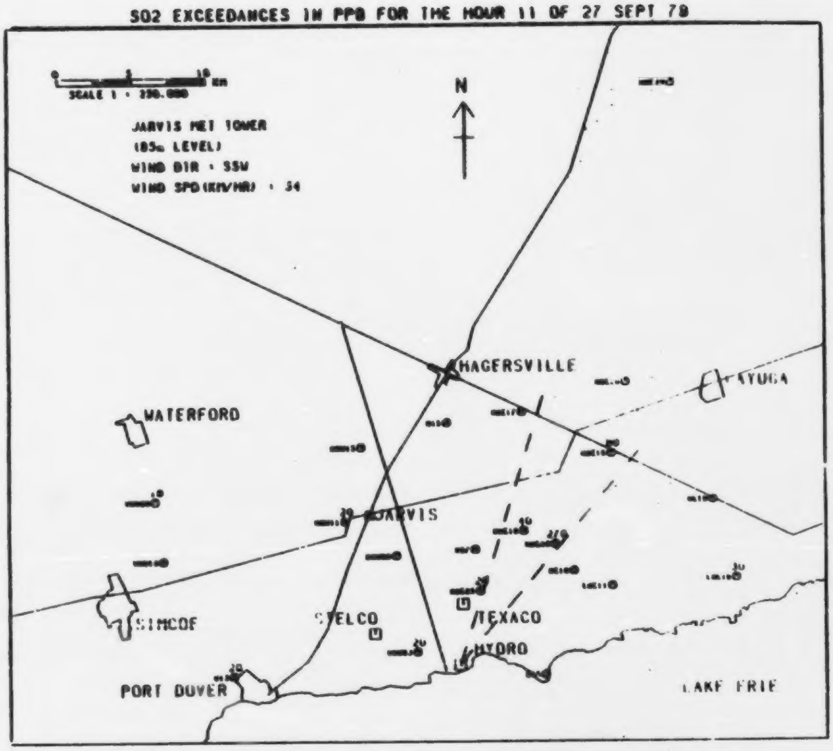
SO_2 EPISODE OF SEPTEMBER 27,1978



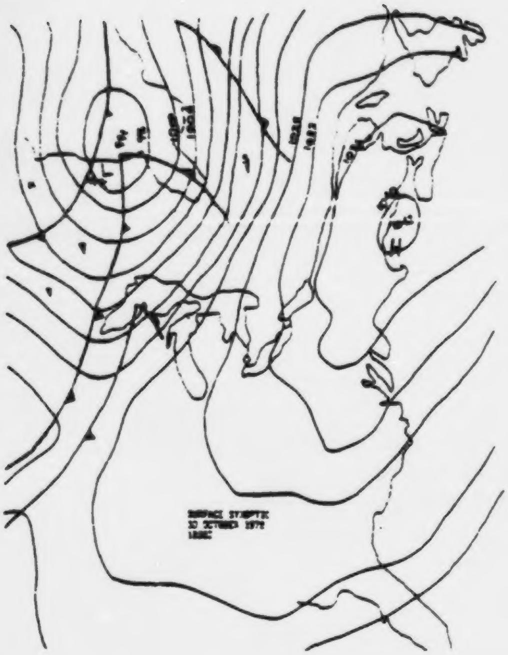


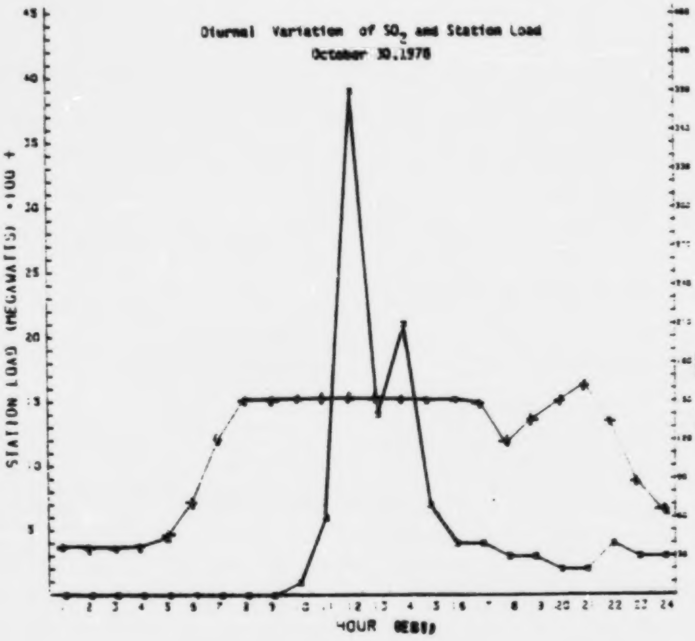


SO2 EXCEEDANCES IN PPB FOR THE HOUR 11 OF 27 SEPT 78

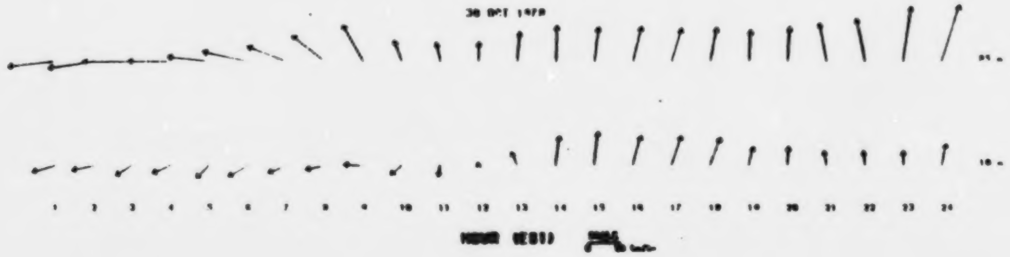


SO_2 EPISODE OF OCTOBER 30,1978

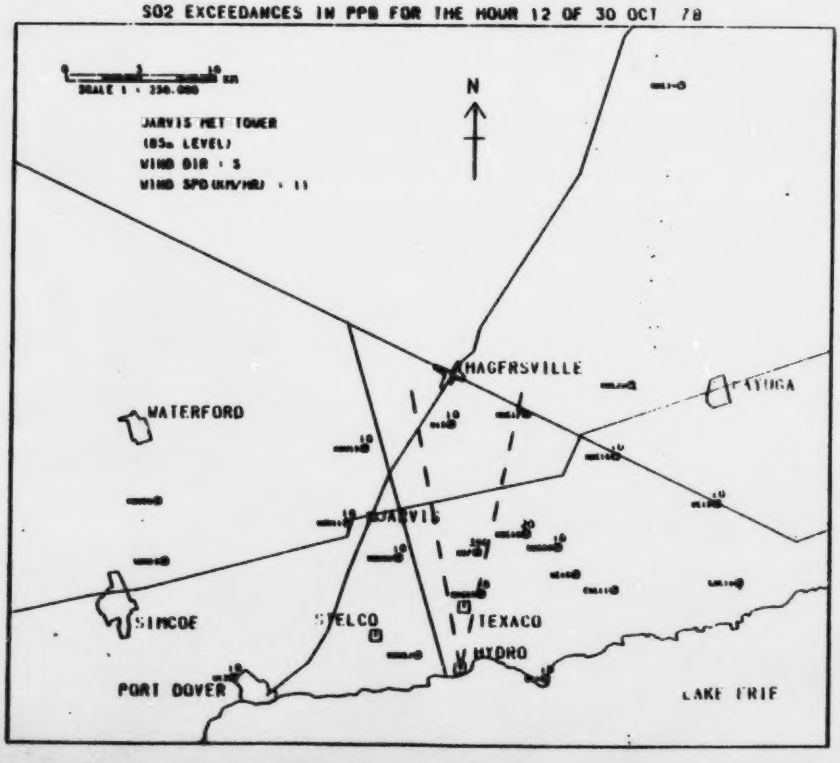




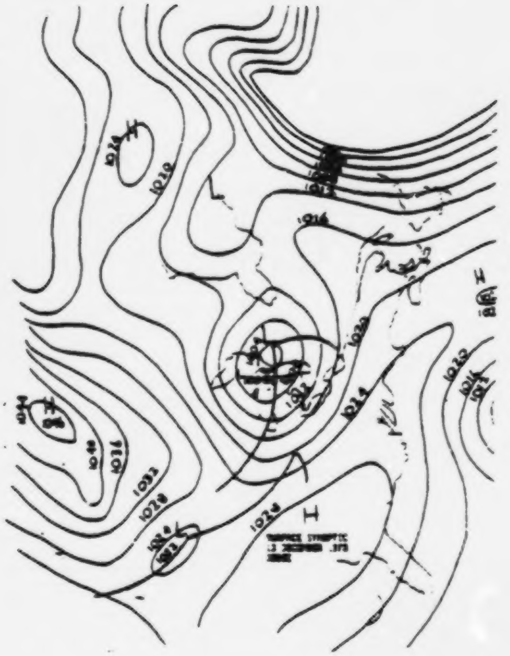
Wind Speed and Direction

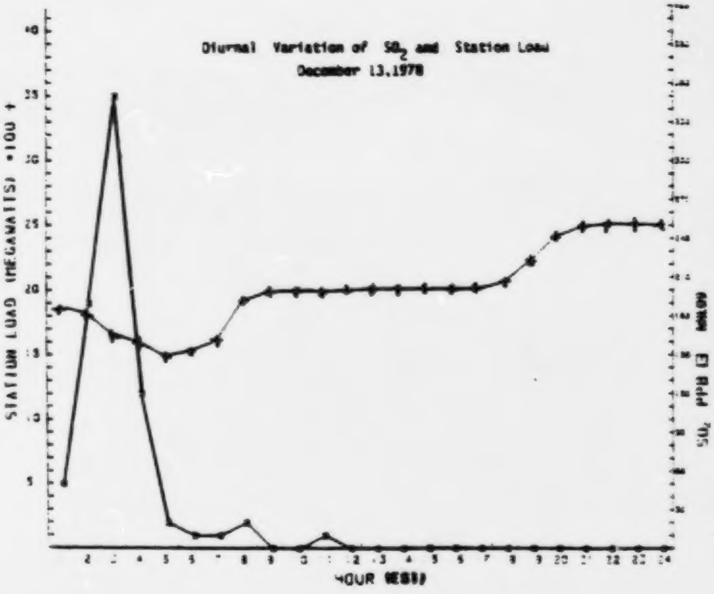


SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 30 OCT 78



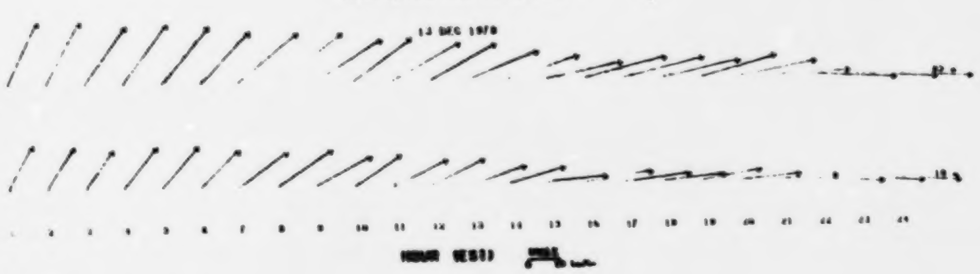
SO_2 EPISODE OF DECEMBER 13,1978



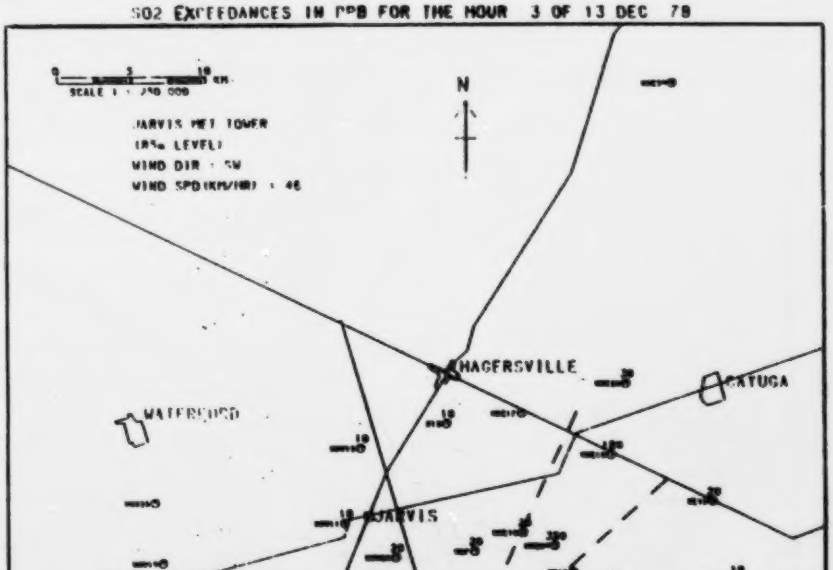


Diurnal Variation of SO_2 and Station Load
December 13,1978

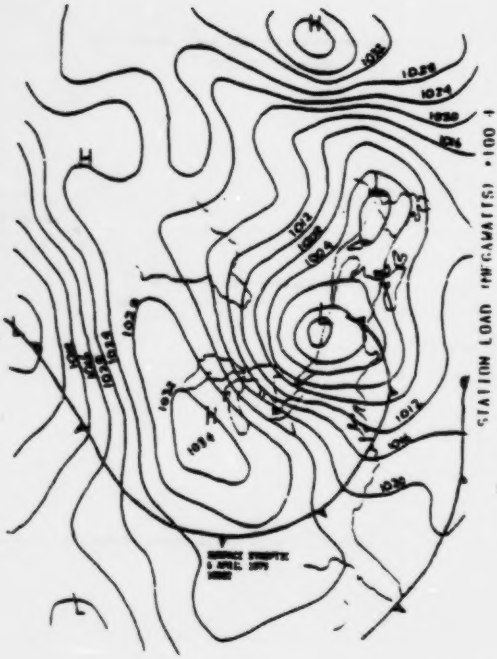
Wind Speed and Direction

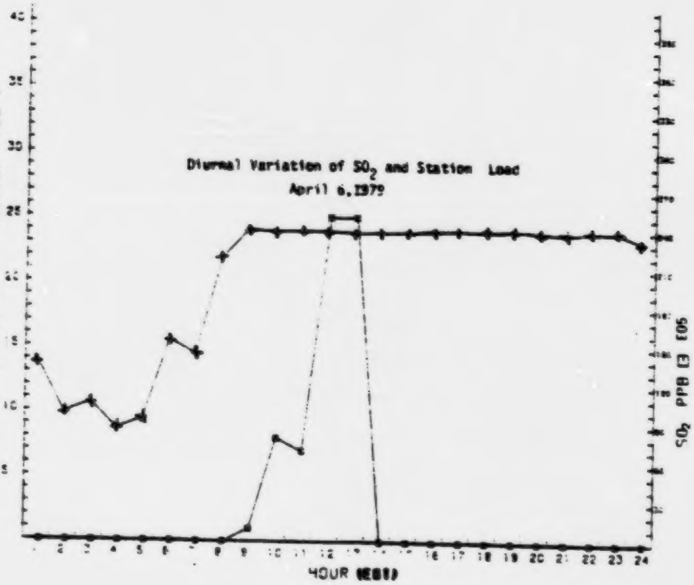


SO2 EXCEEDANCES IN PPB FOR THE HOUR 3 OF 13 DEC 78



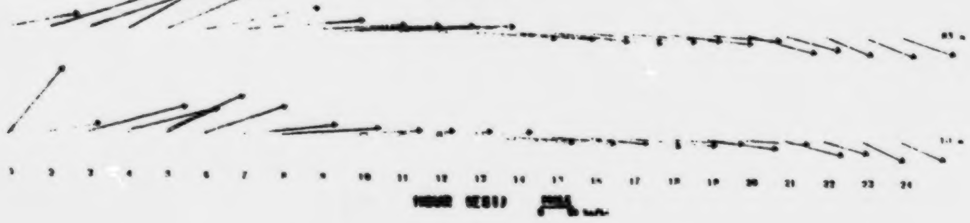
SO_2 EPISODE OF APRIL 6,1979



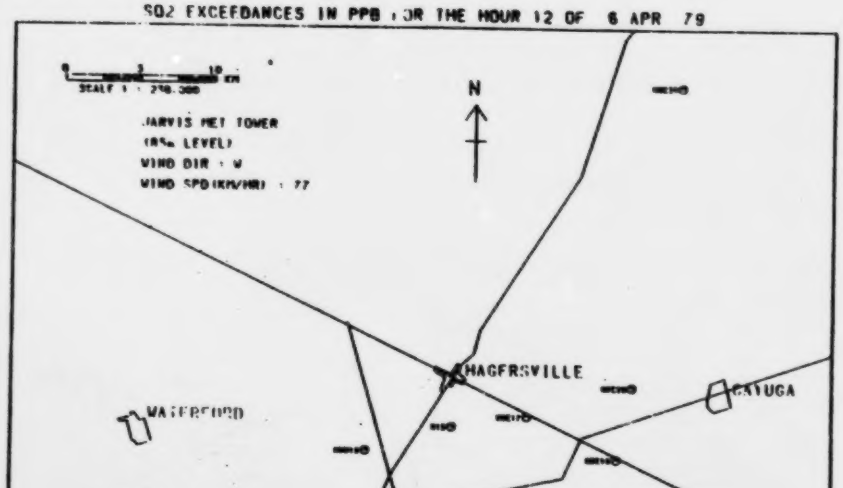

Diurnal Variation of SO_2 and Station Load
April 6,1979

Wind Speed and Direction

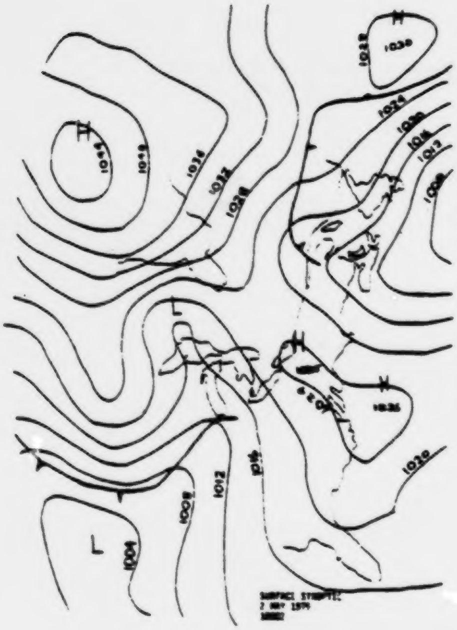
6 APR 1979

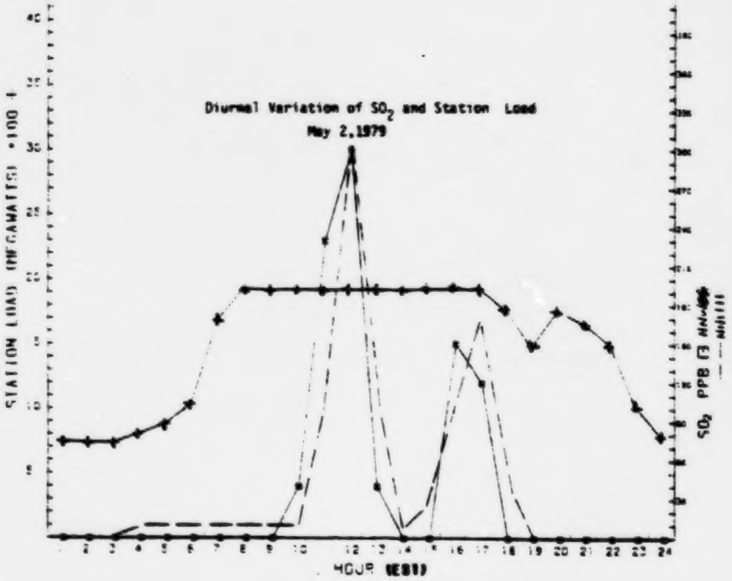


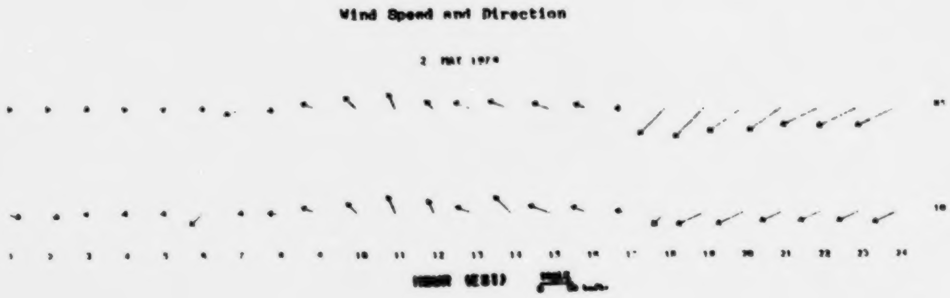
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 6 APR 79



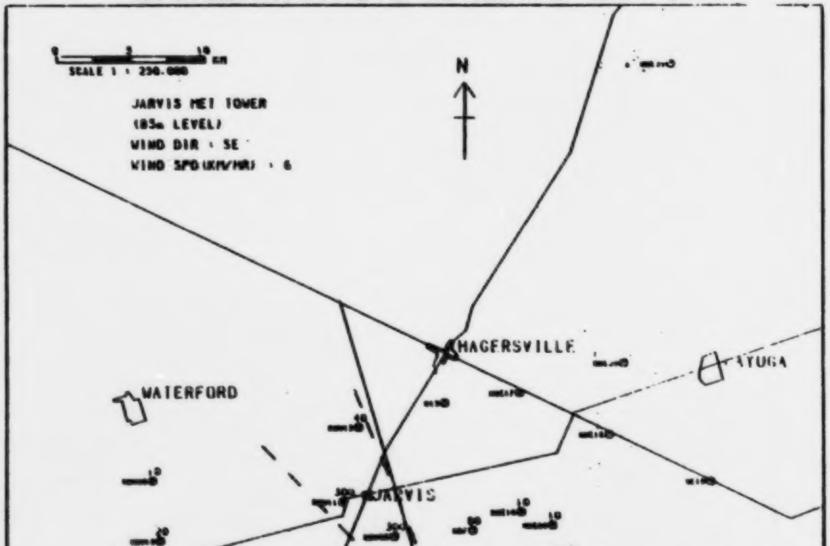
SO_2 EPISODE OF MAY 2,1979



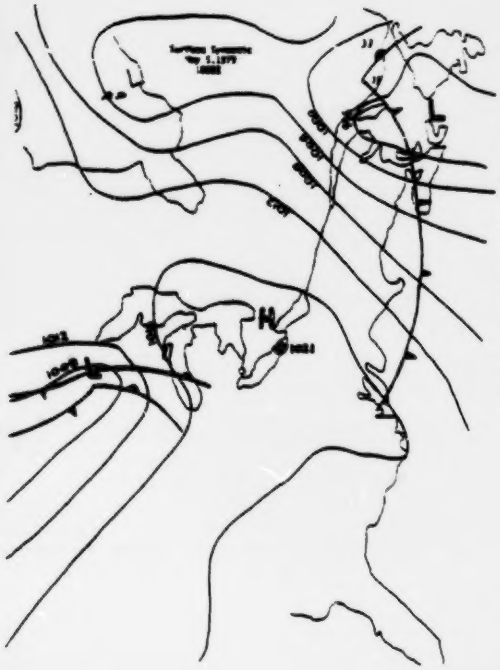


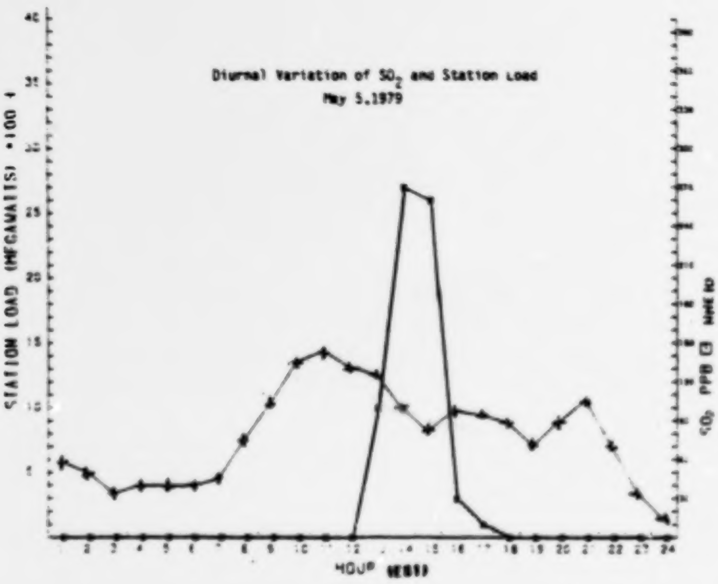


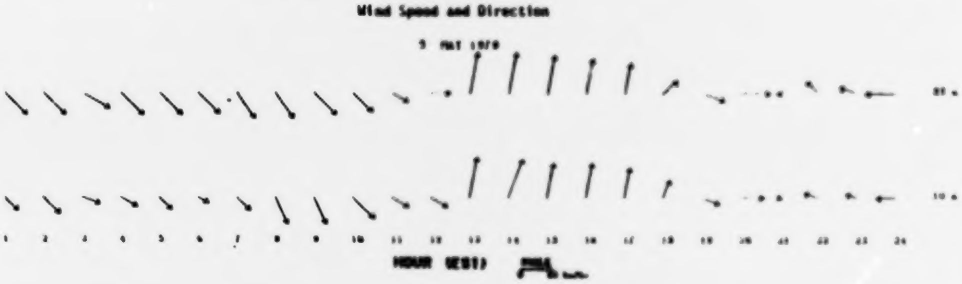
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 2 MAY 79



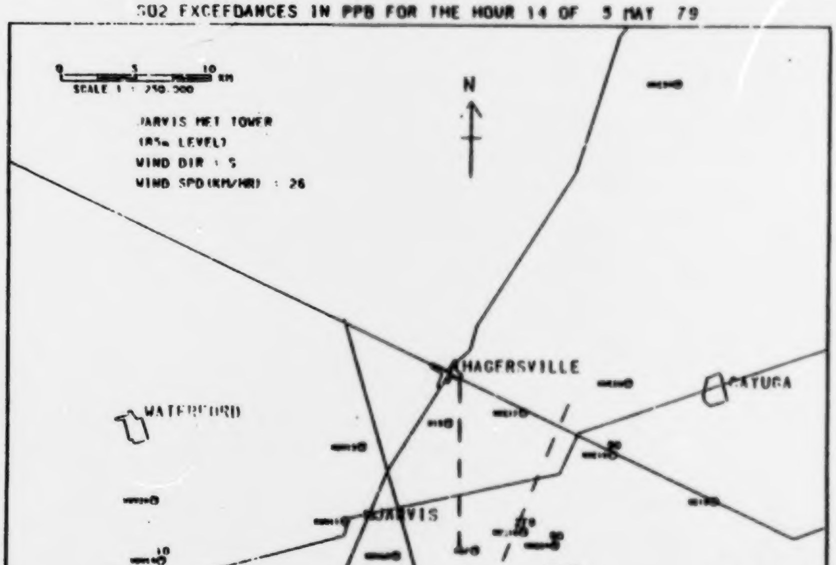
SO$_2$ EPISODE OF MAY 5,1979



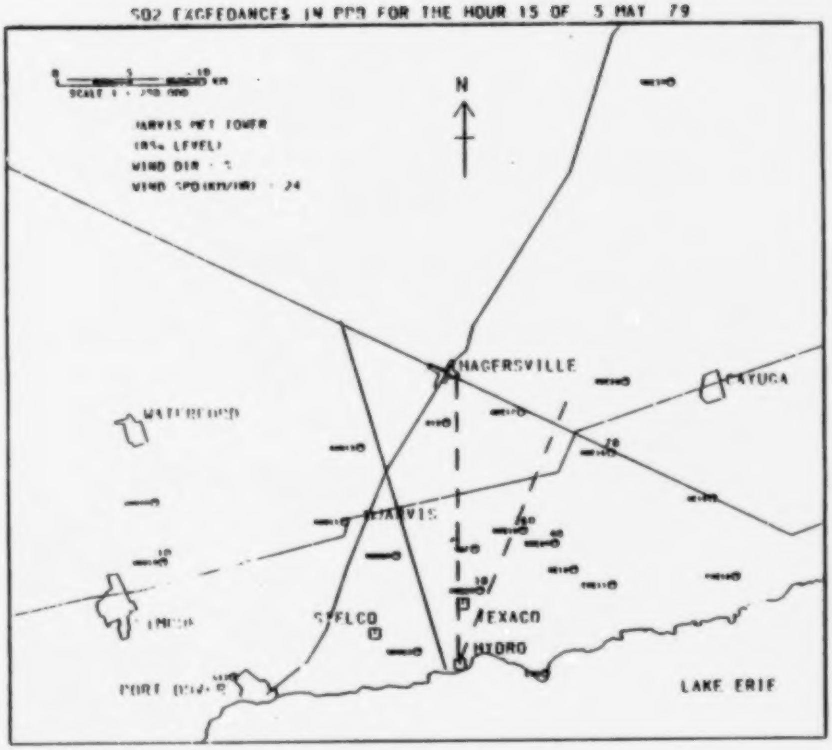




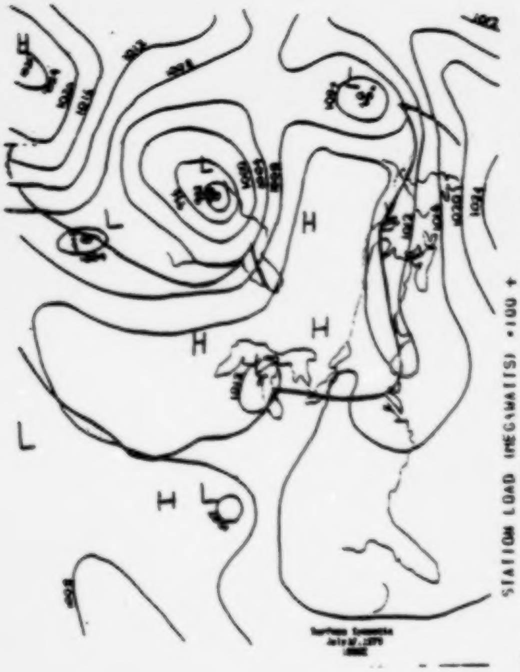
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 5 MAY 79

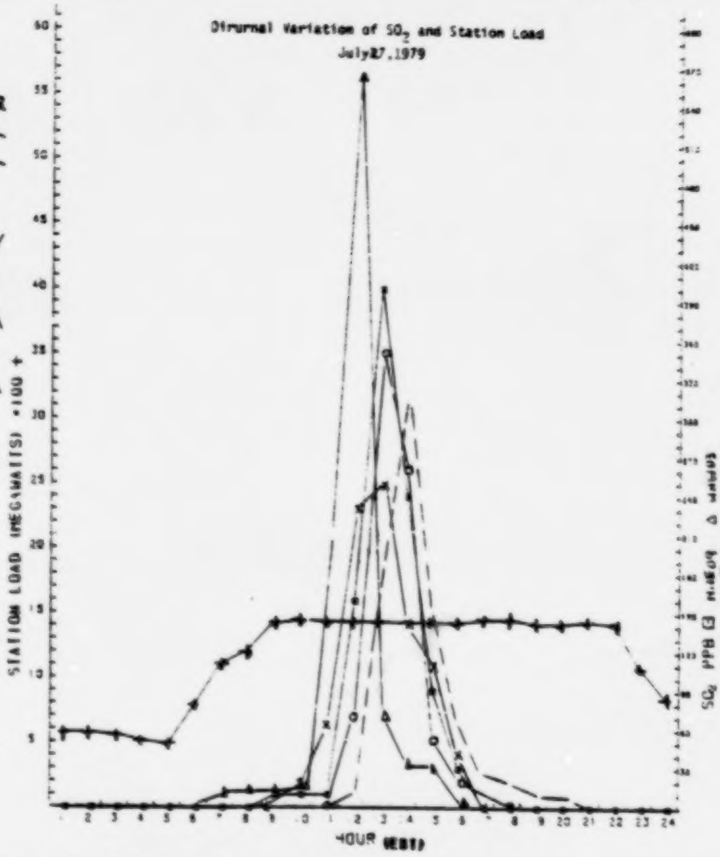


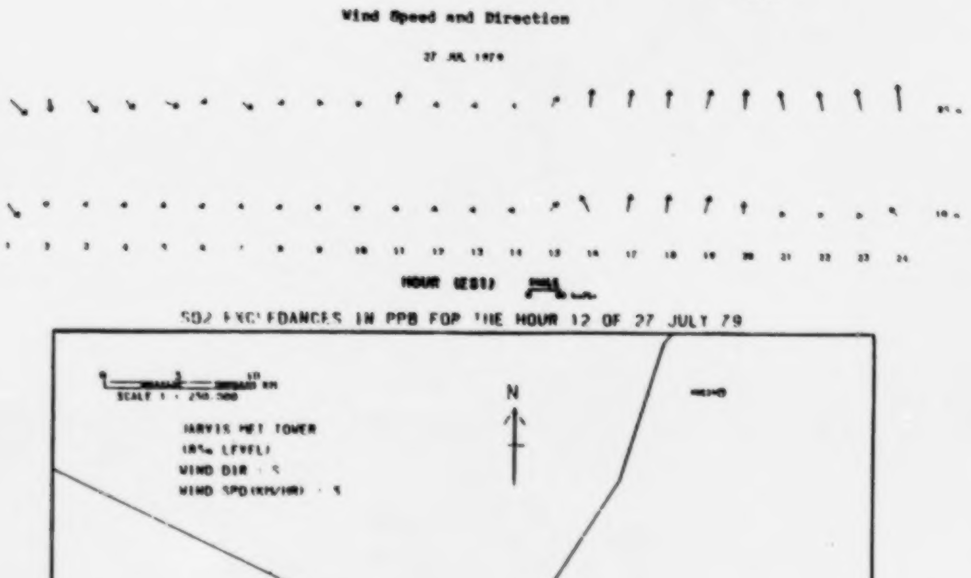
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 5 MAY 79



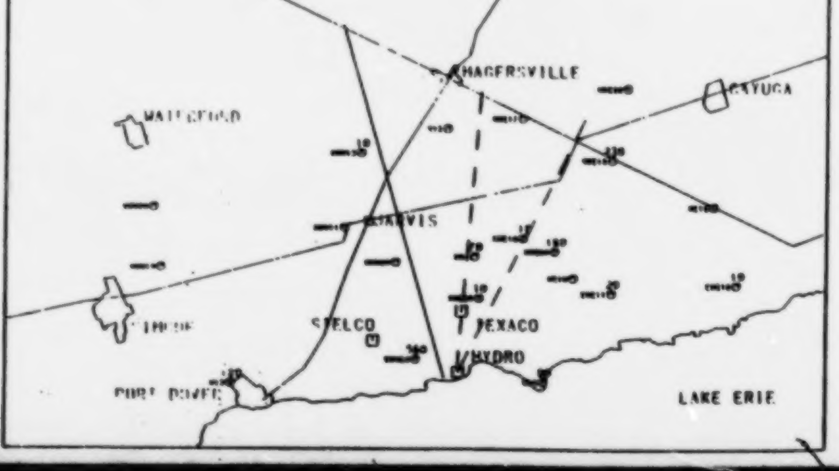
SO_2 EPISODE OF JULY 27,1979



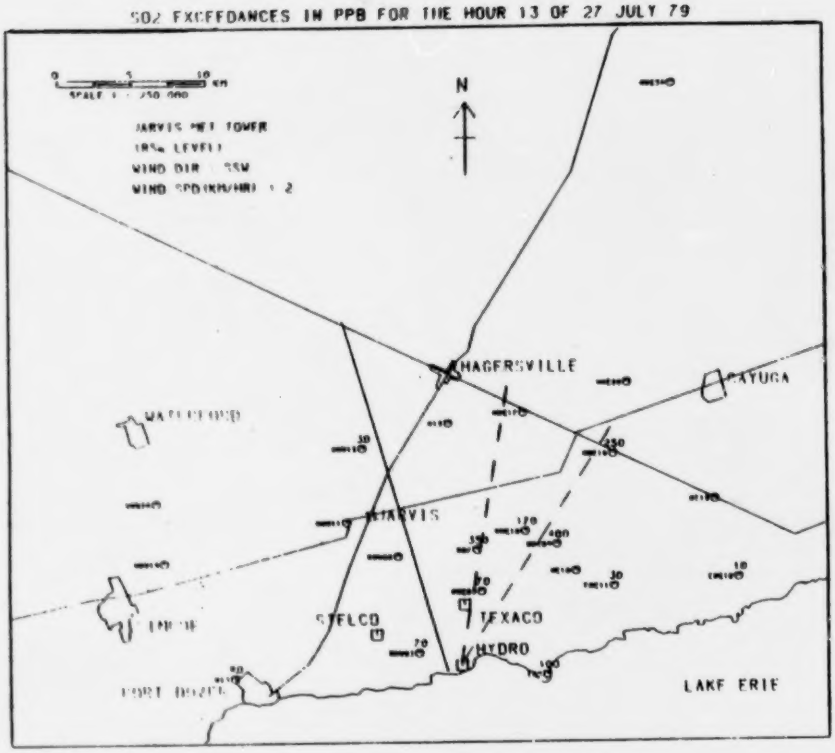




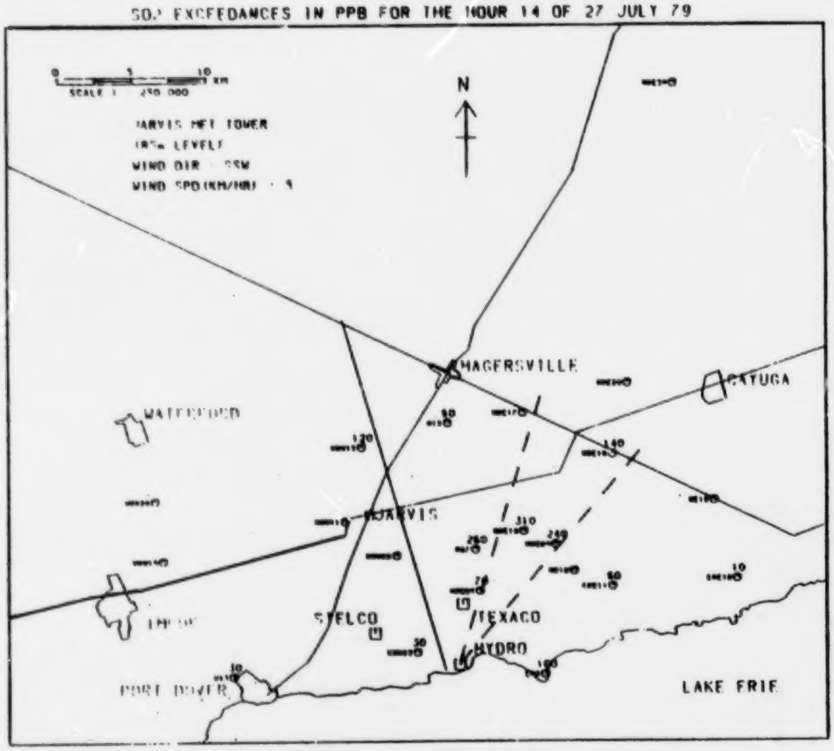
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 27 JULY 79

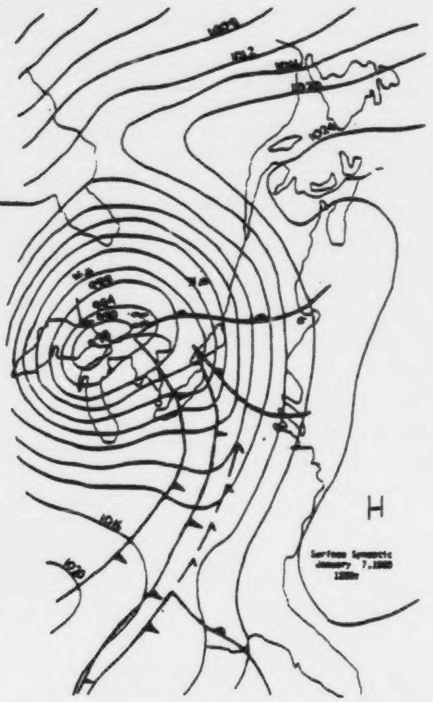


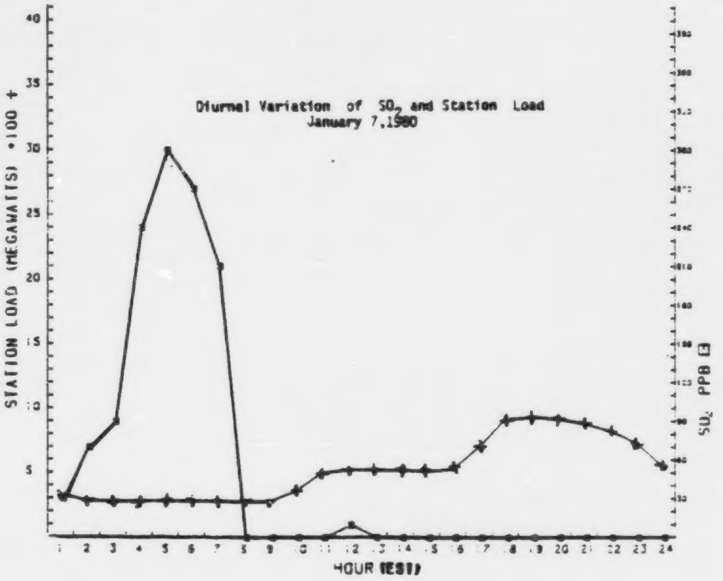
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 27 JULY 79

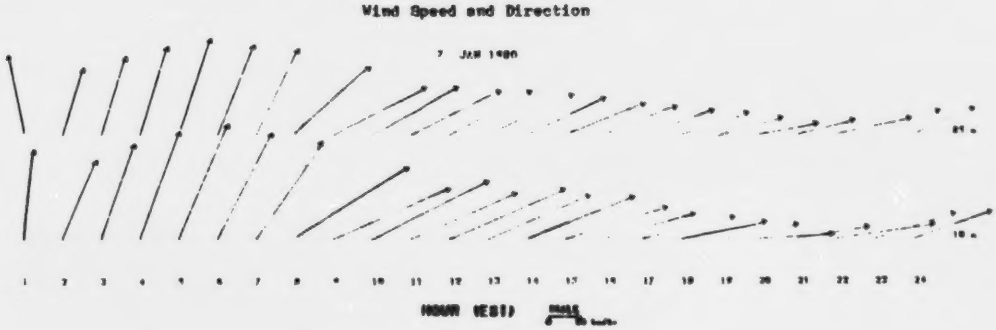


SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 27 JULY 79

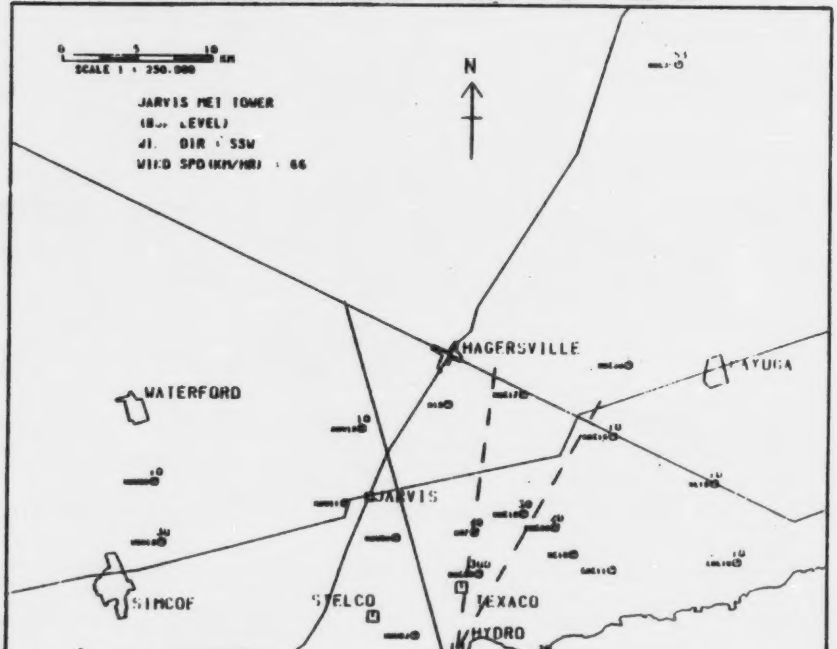




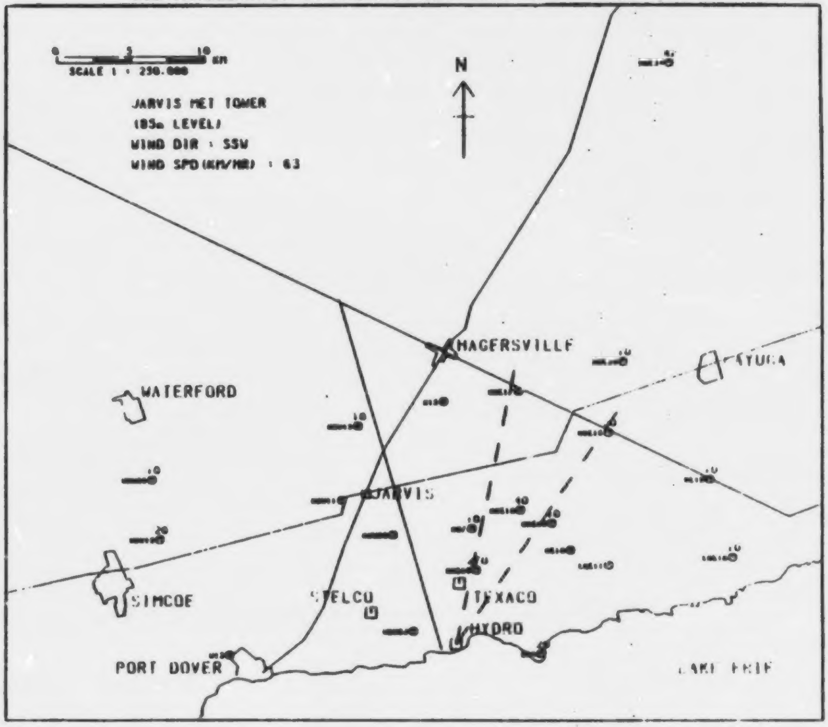


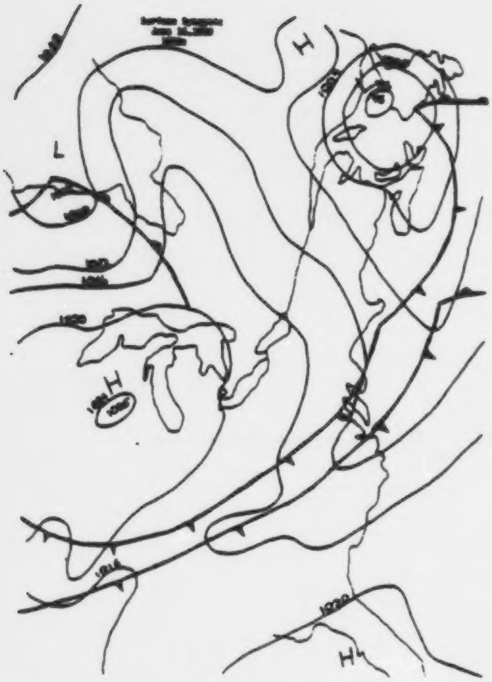


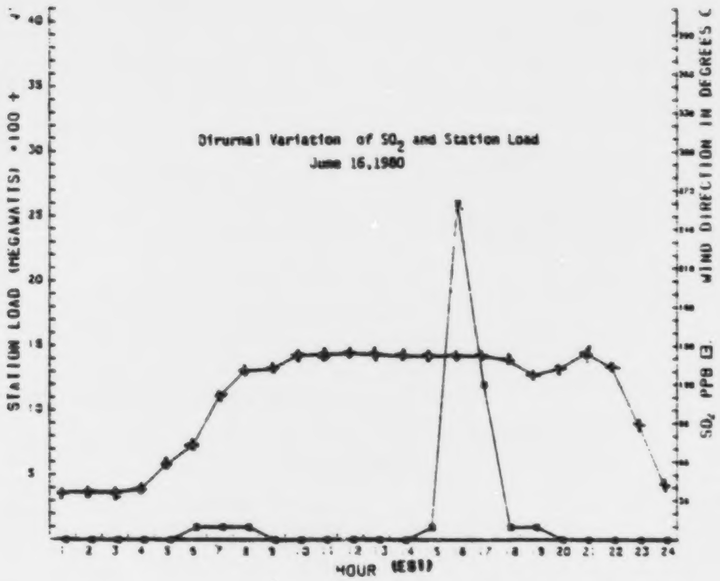
SO2 EXCEEDANCES IN PPB FOR THE HOUR 5 OF 7 JAN '80



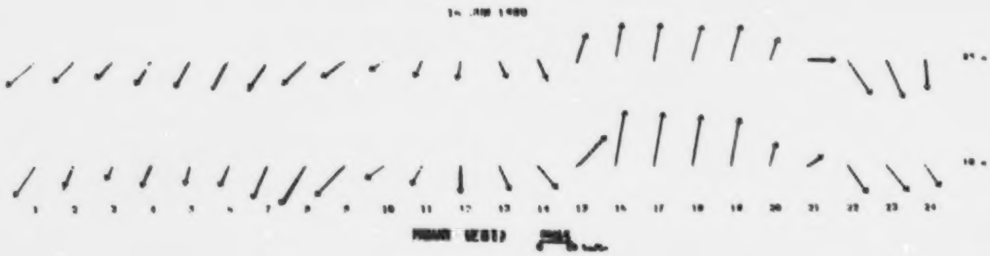
SO2 EXCEEDANCES IN PPB FOR THE HOUR 6 OF 7 JAN 80



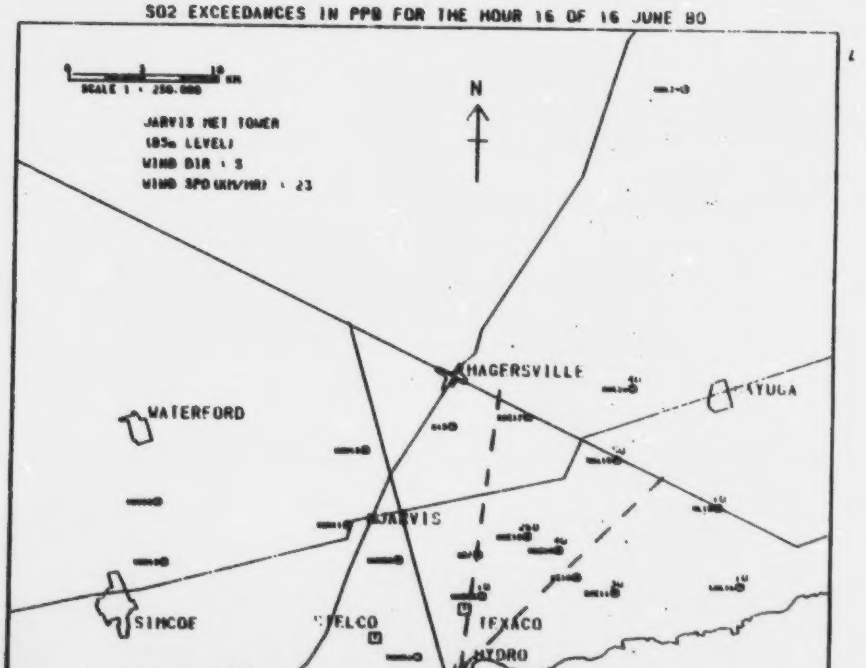




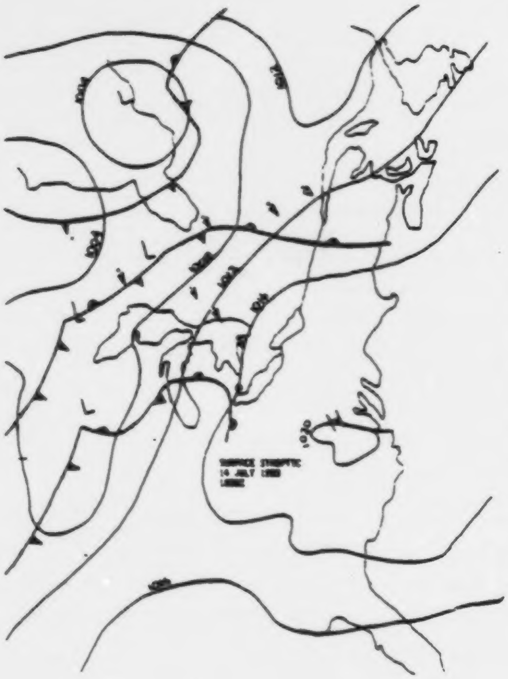
Wind Speed and Direction

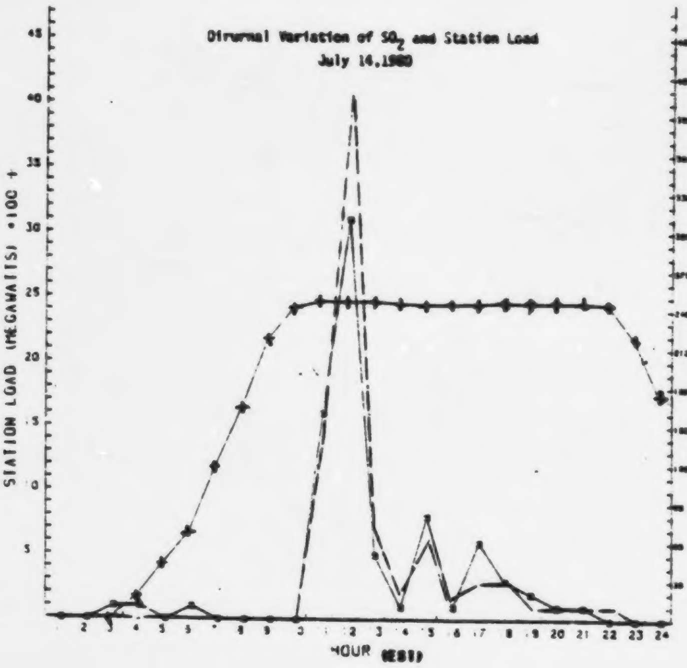


SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 16 JUNE 80

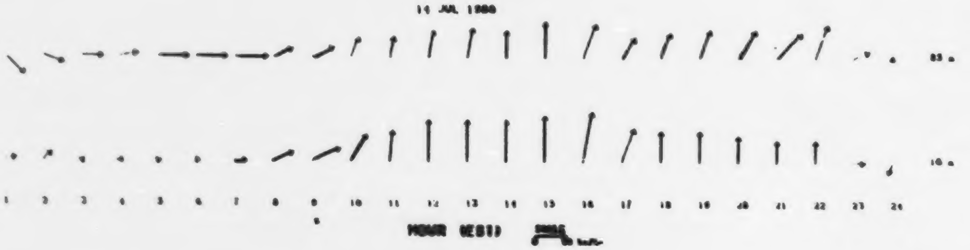


SO_2 EPISODE OF JULY 14,1980

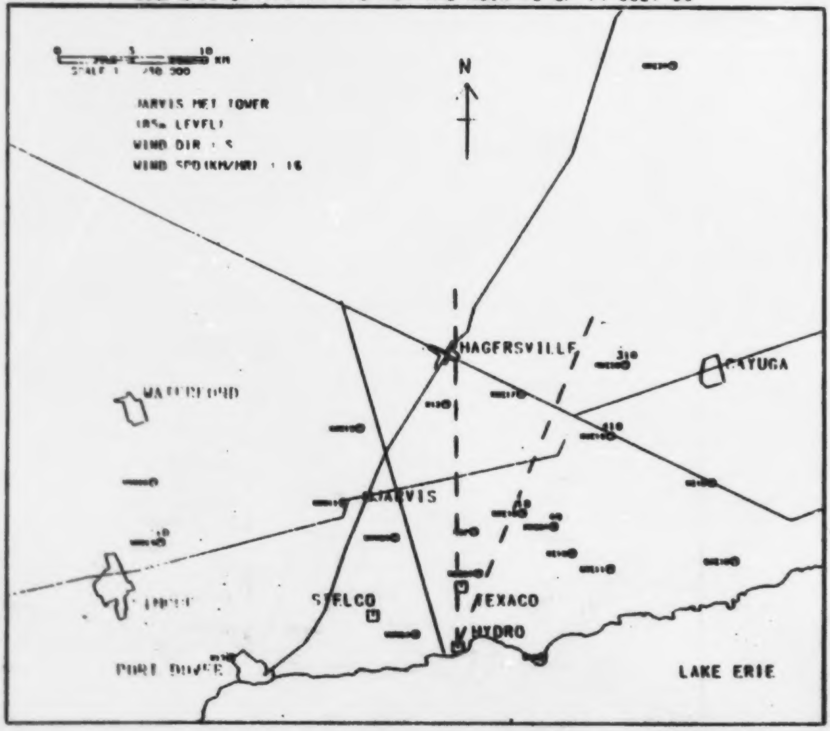




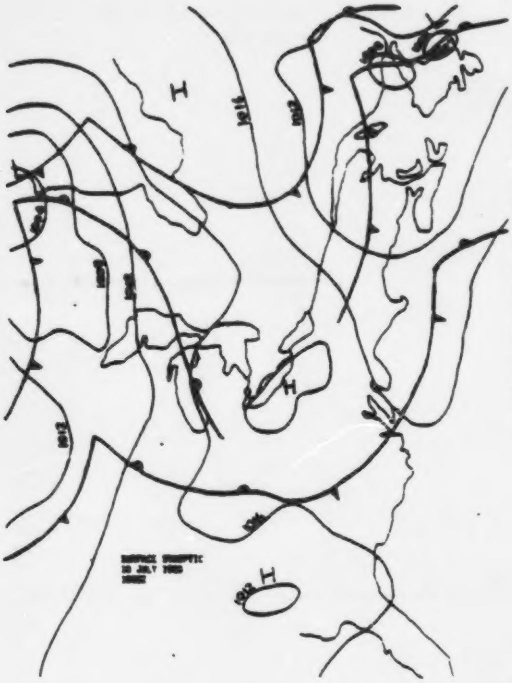
Wind Speed and Direction

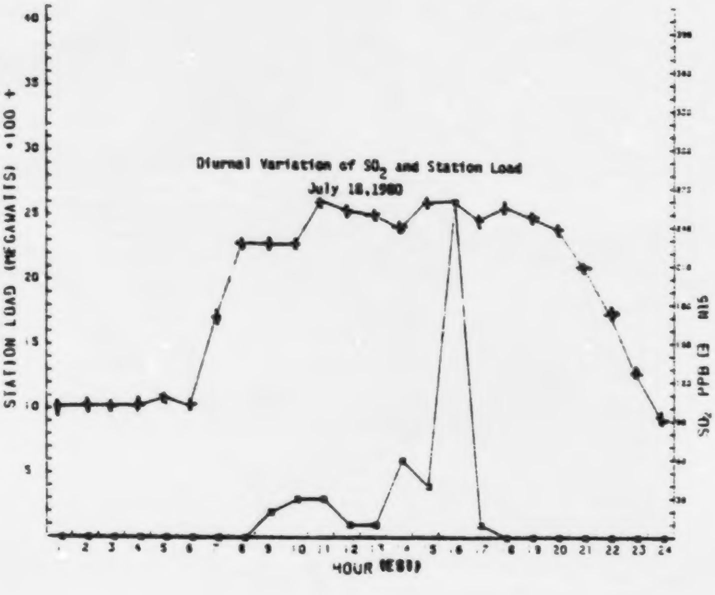


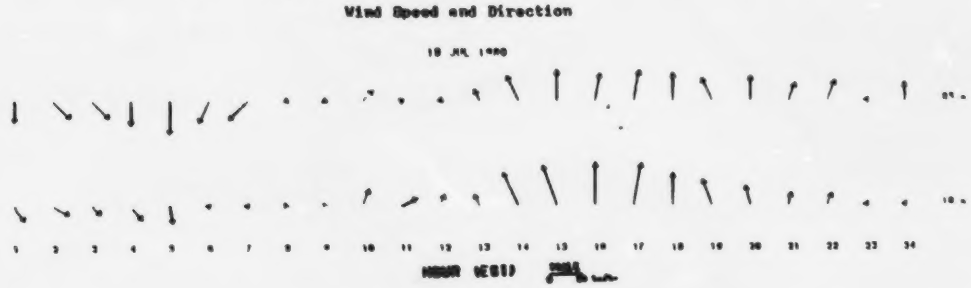
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 14 JULY 80



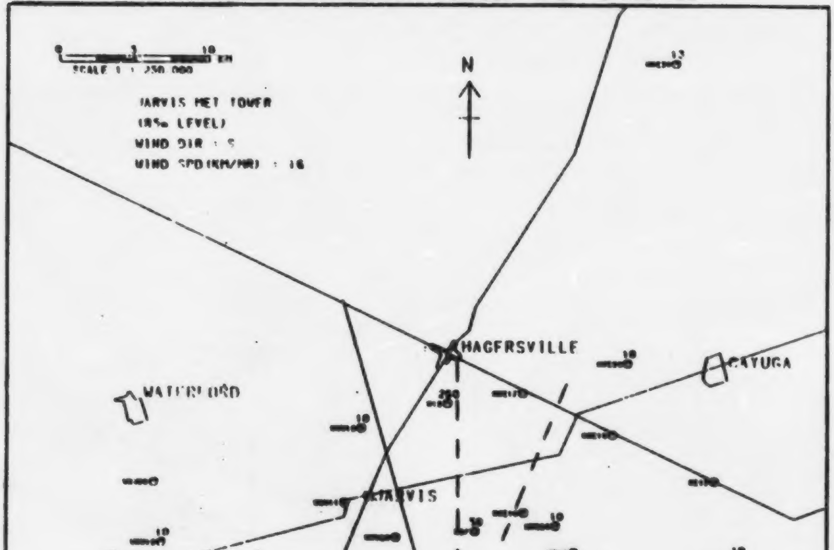
SO_2 EPISODE OF JULY 18,1980

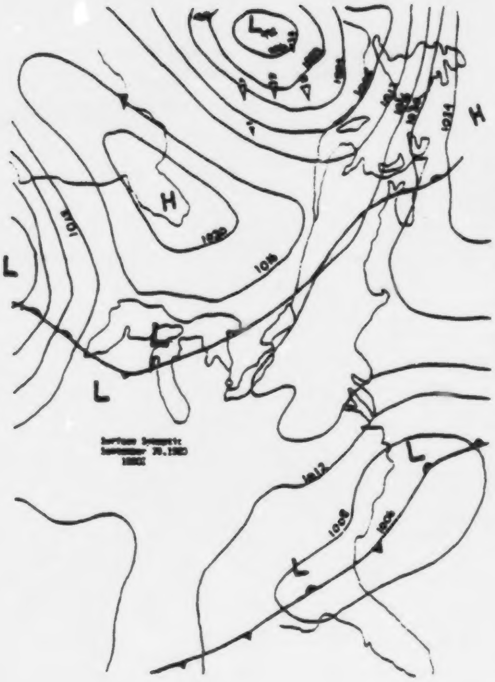


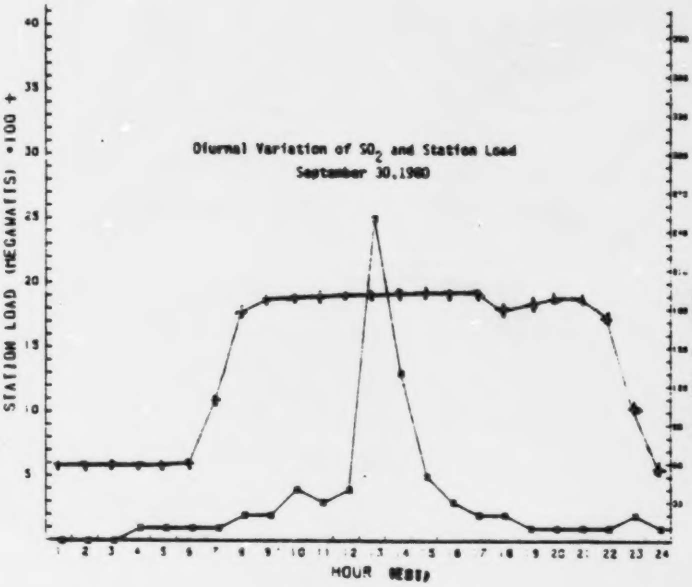




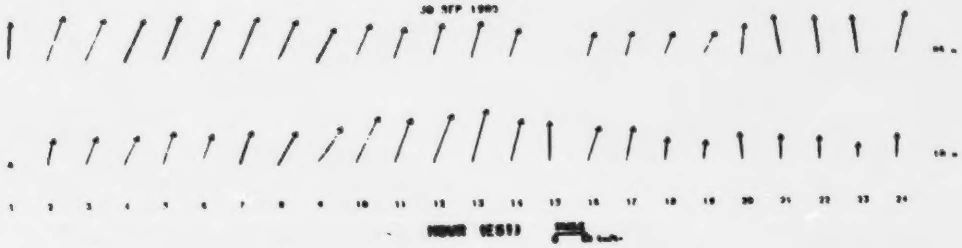
SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 18 JULY 80



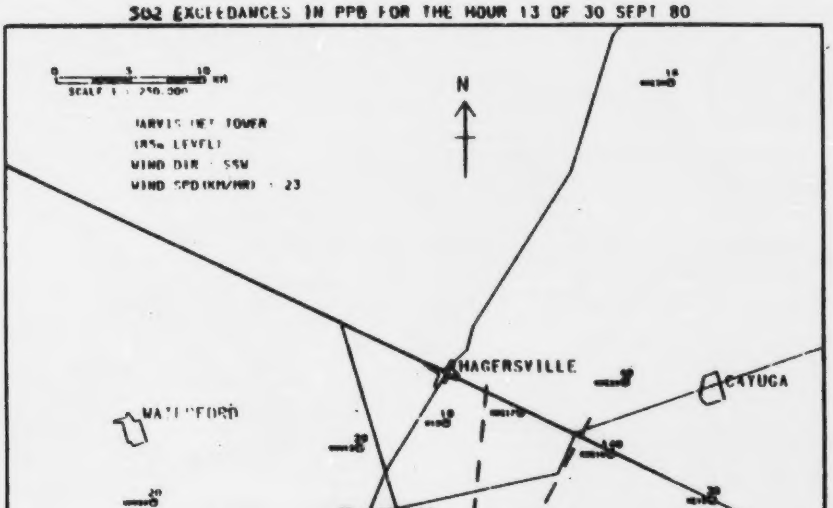




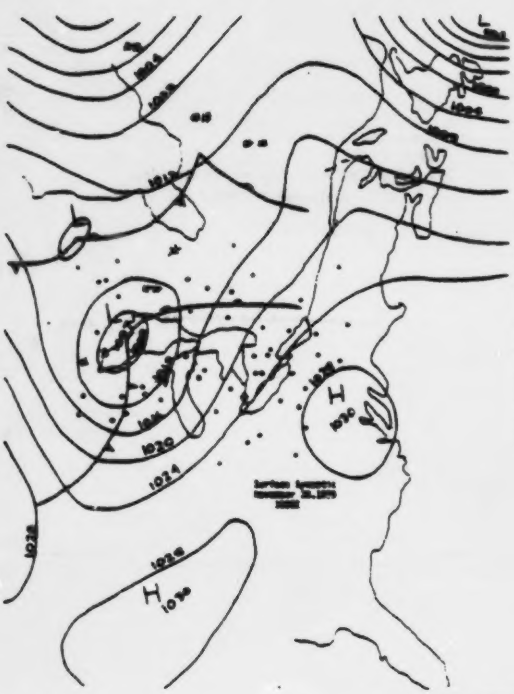
Wind Speed and Direction

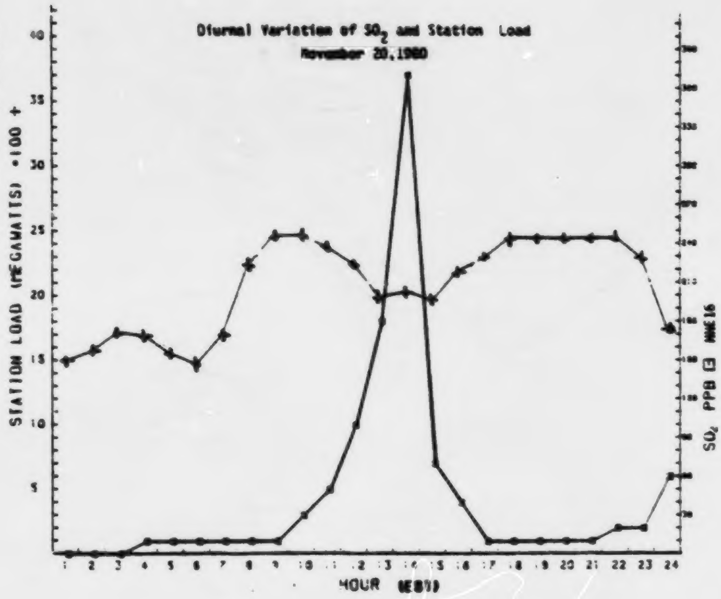


SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 30 SEPT 80

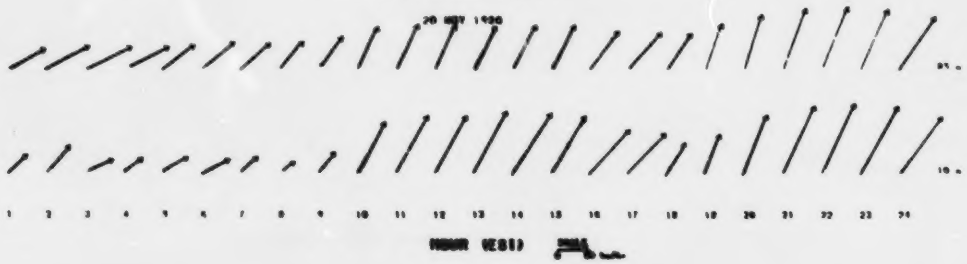


SO_2 EPISODE OF NOVEMBER 20,1980

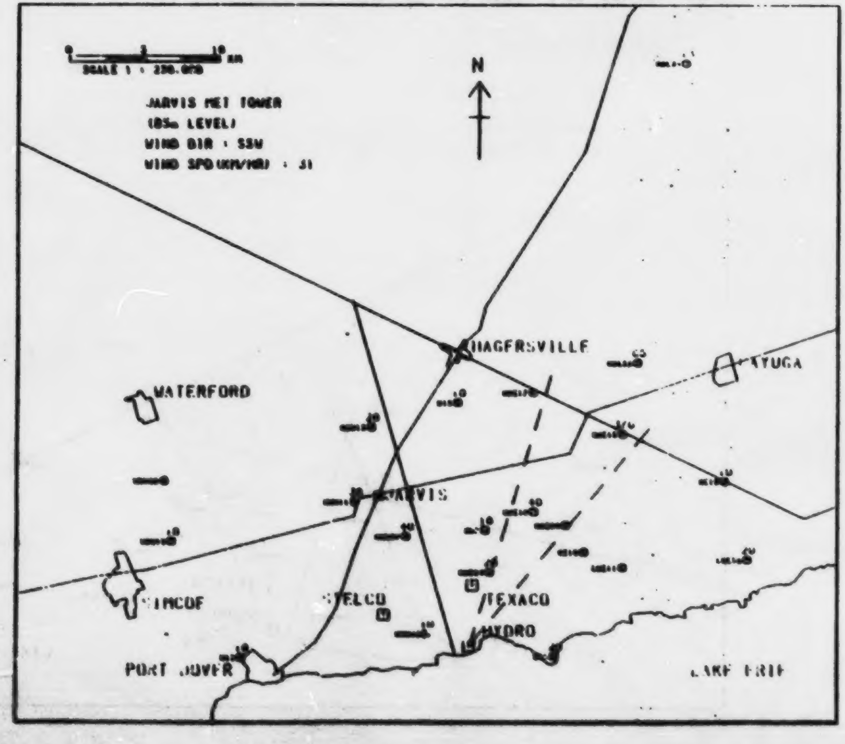


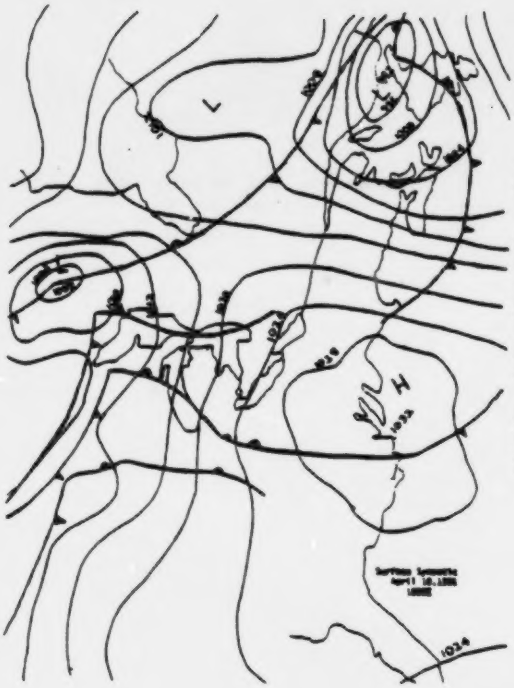


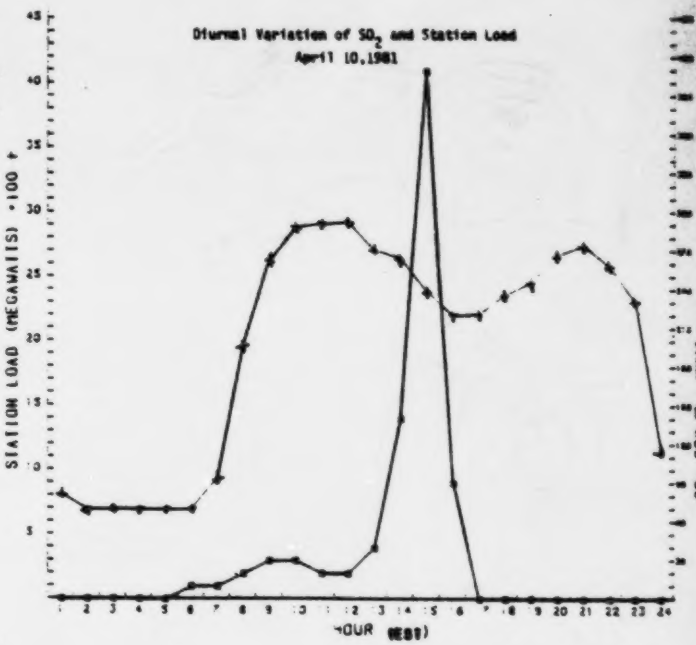
Wind Speed and Direction



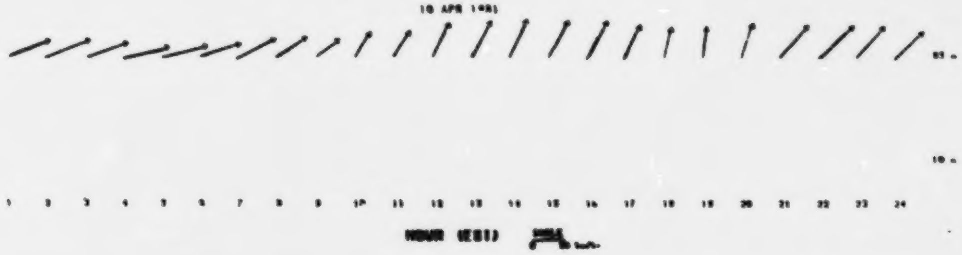
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 20 NOV 80



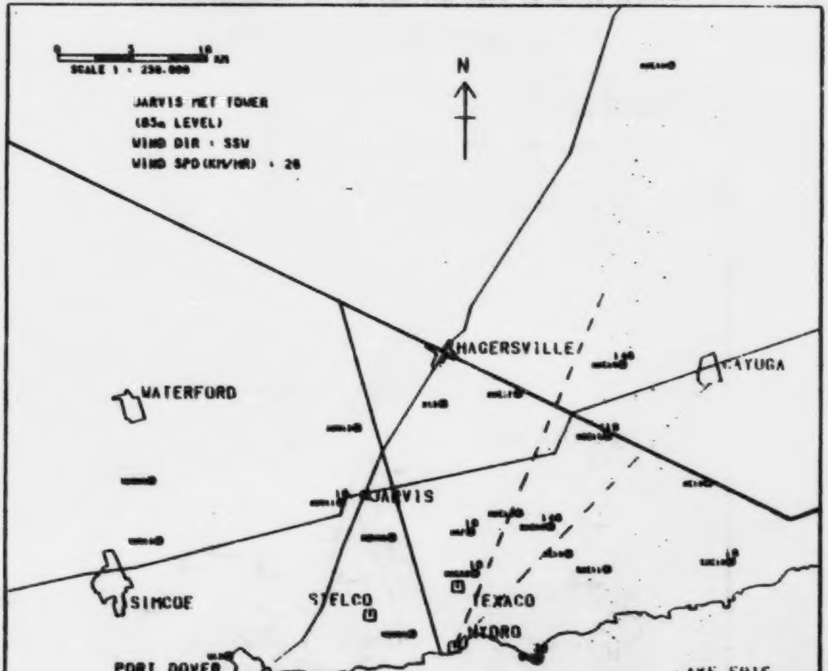


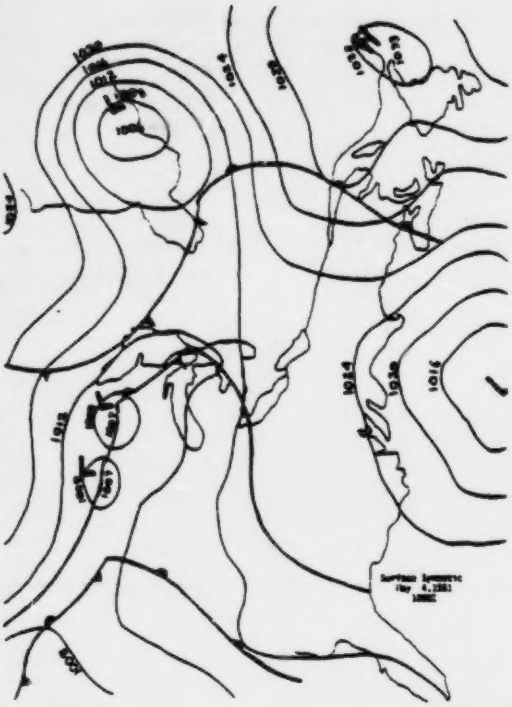

Diurnal Variation of SO$_2$ and Station Load
April 10,1981

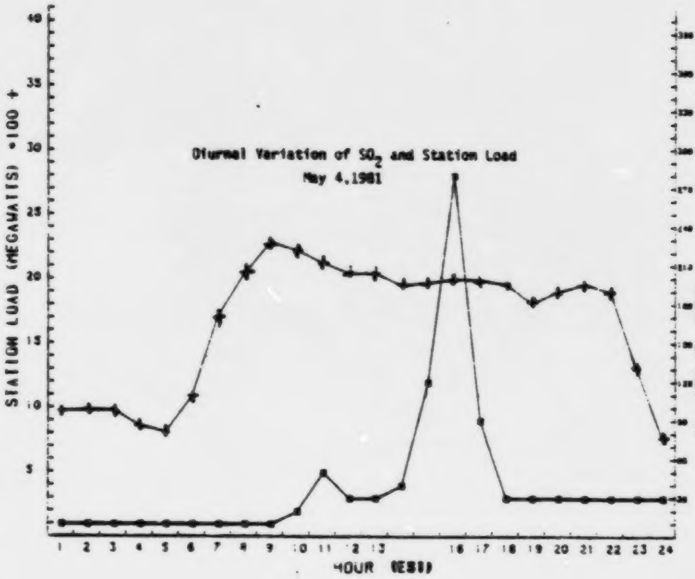
Wind Speed and Direction

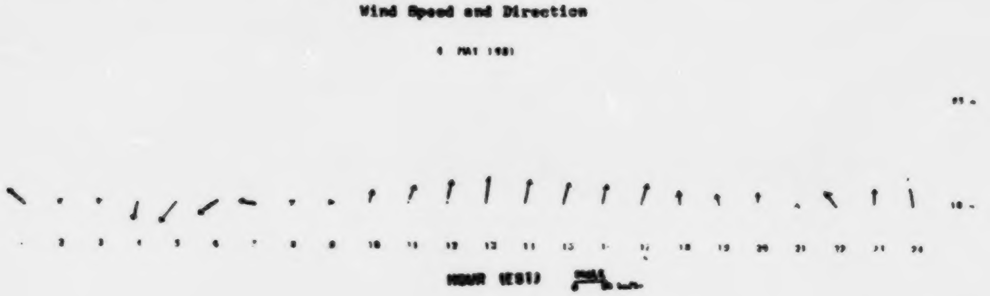


SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 10 APR .81

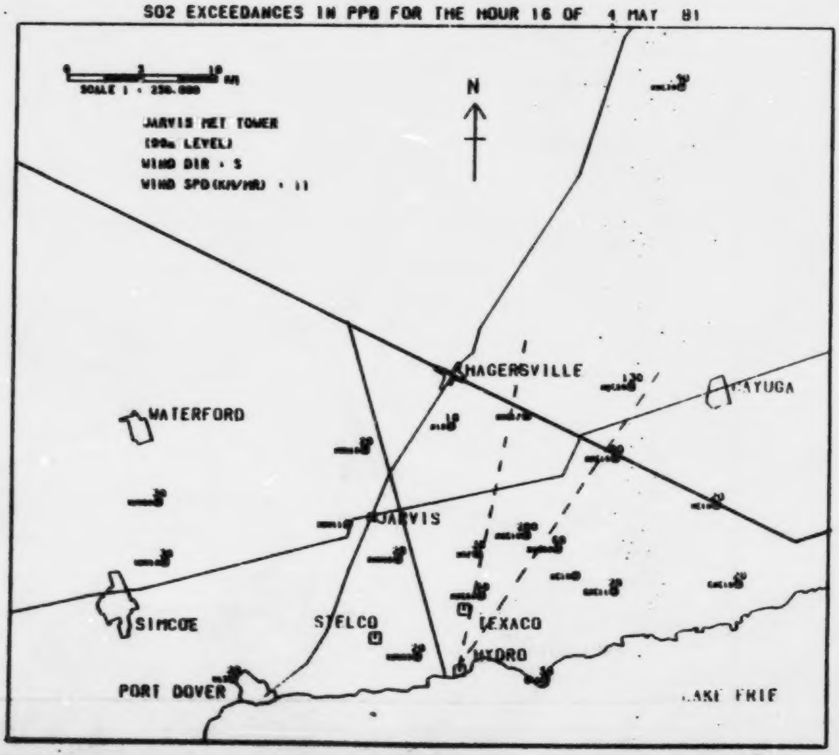




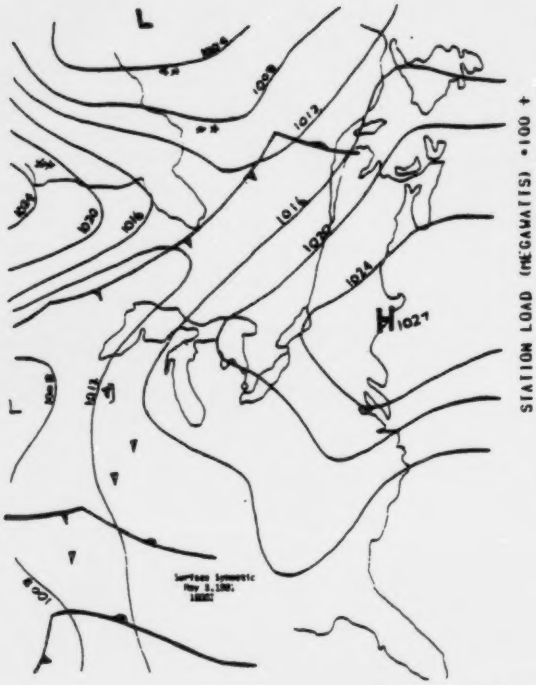


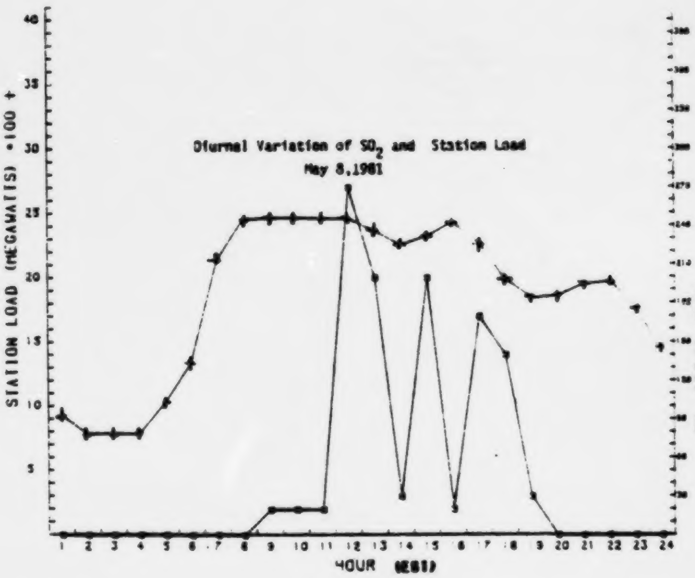


SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 4 MAY 81

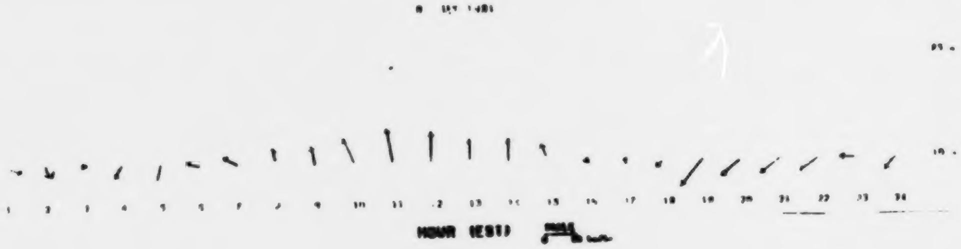


SO$_2$ EPISODE OF MAY 8,1981

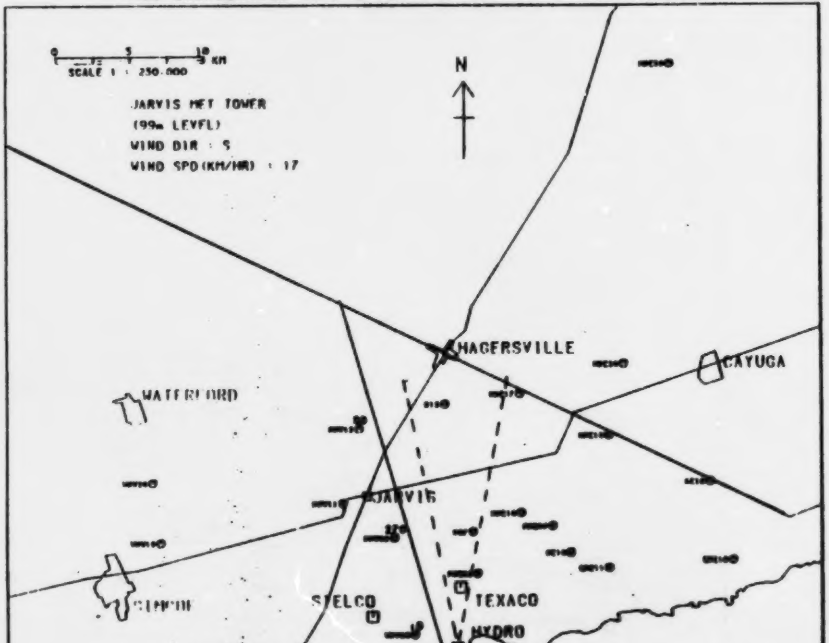




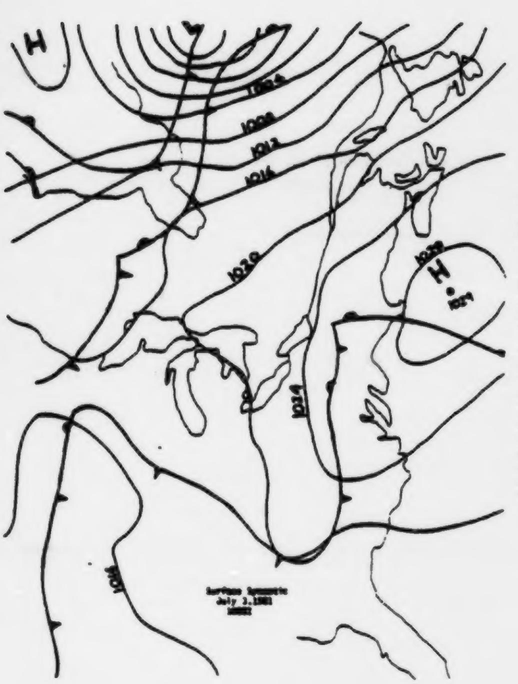
Wind Speed and Direction

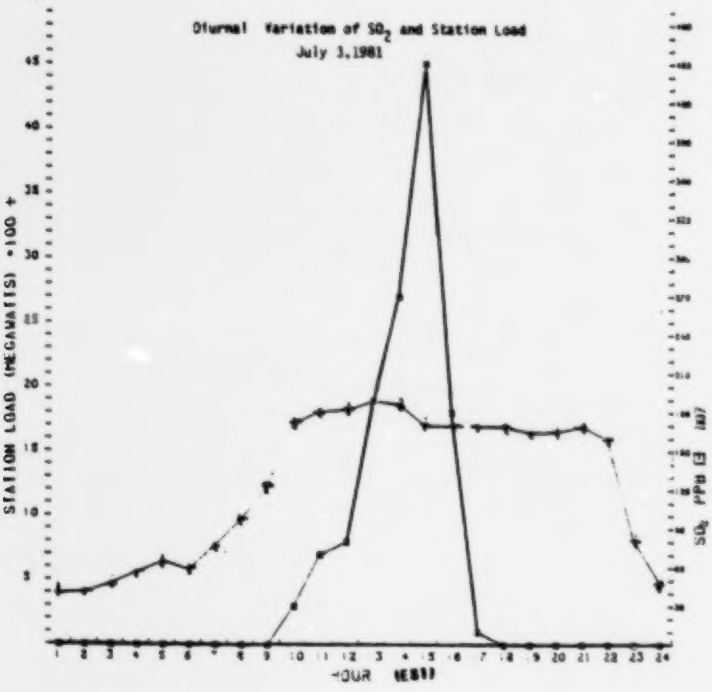


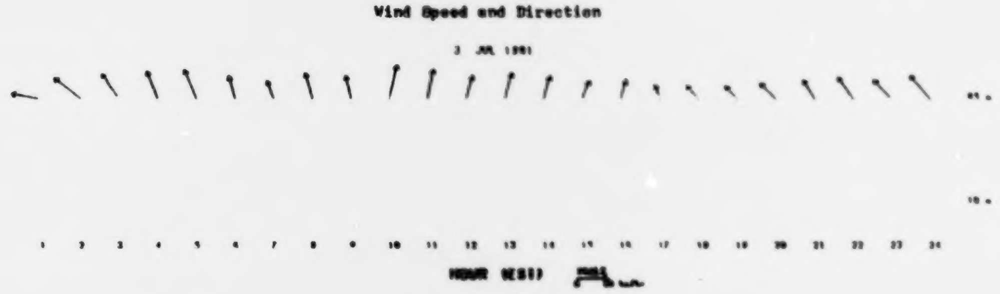
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 8 MAY 81



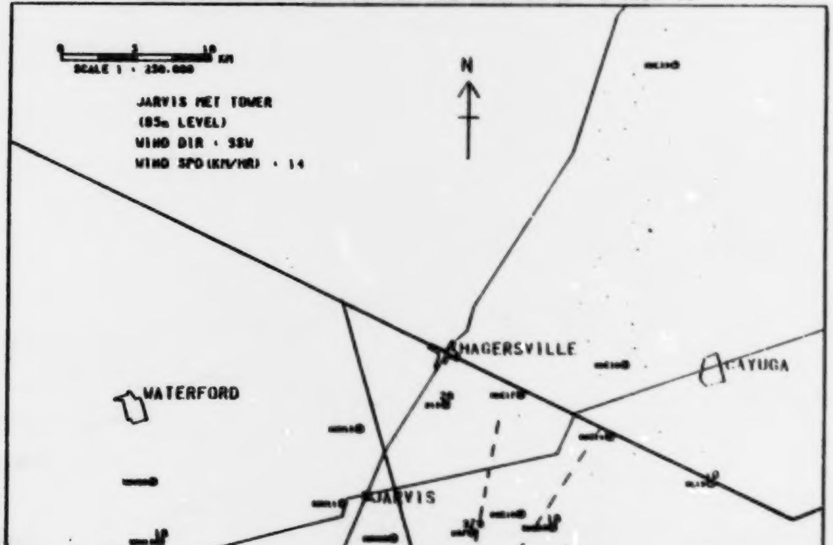
SO_2 EPISODE OF JULY 3,1981



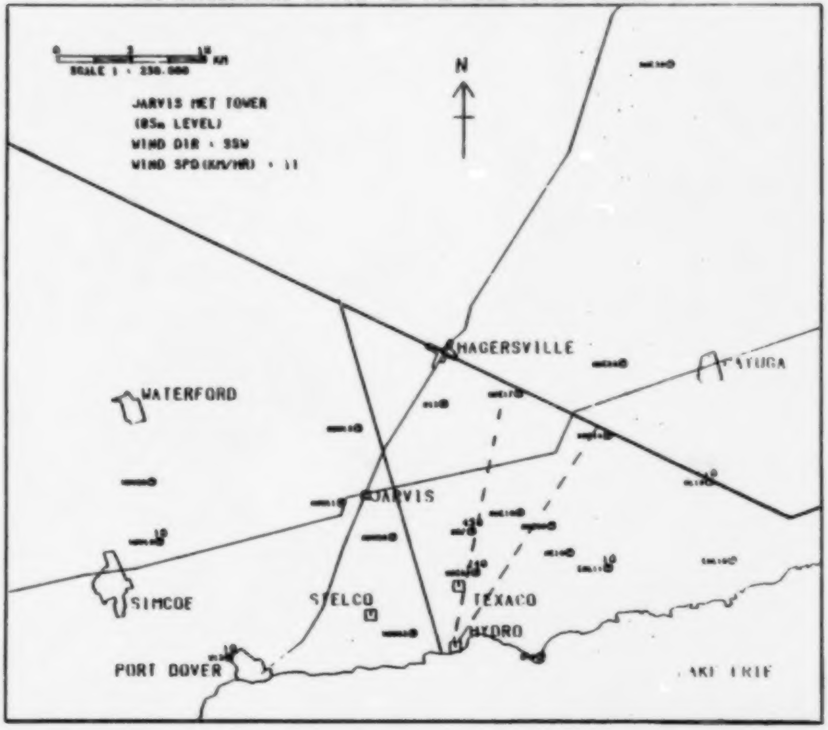




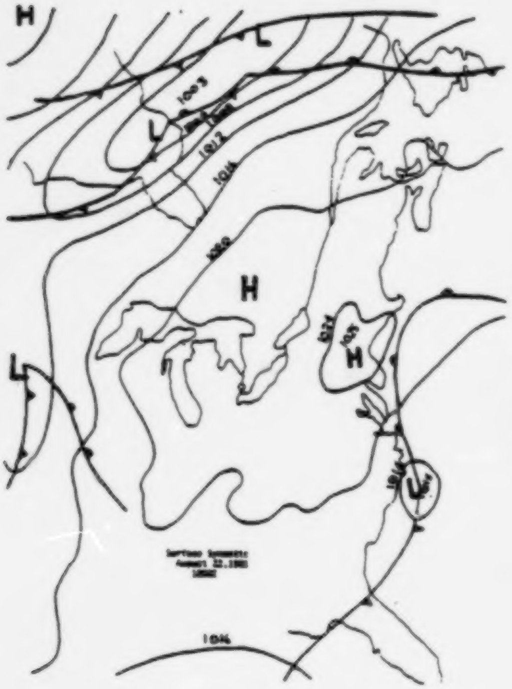
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 3 JULY 81

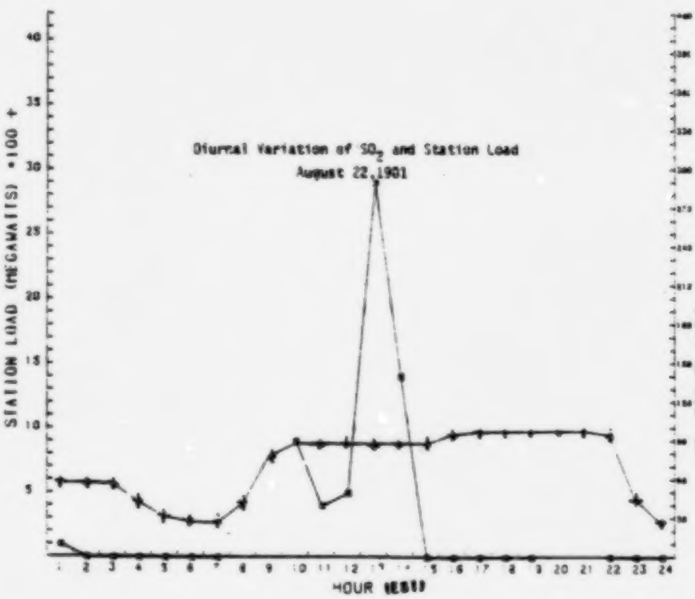


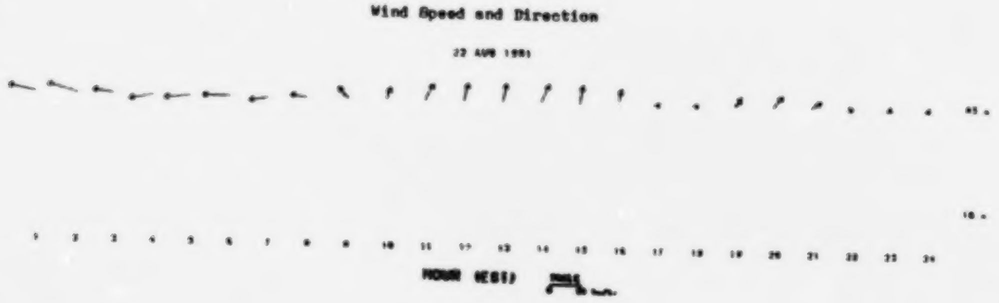
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 3 JULY 81



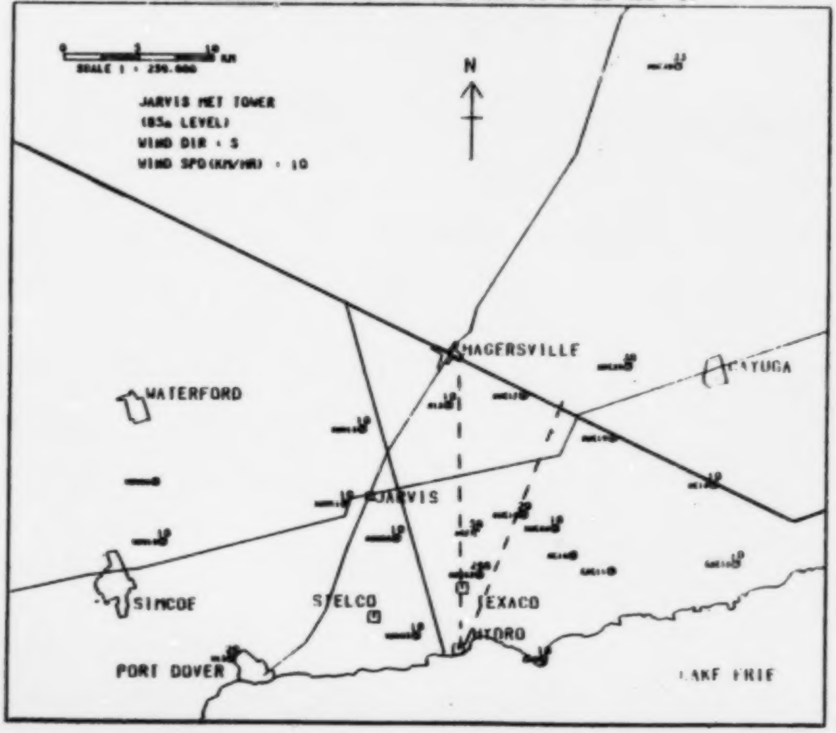
SO_2 EPISODE OF AUGUST 22,1981



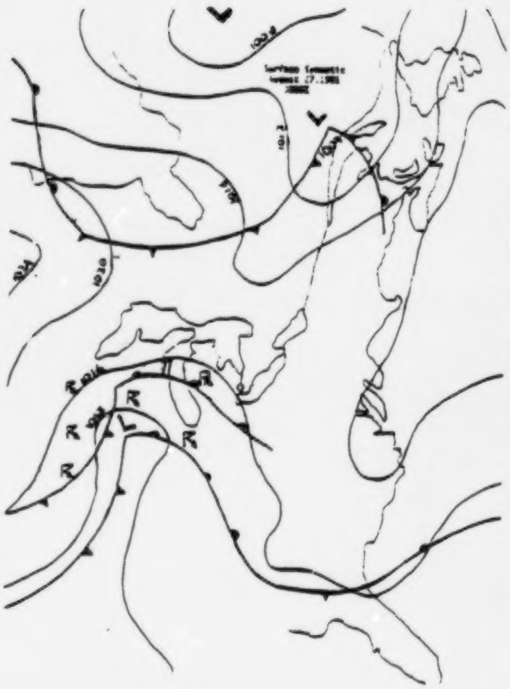


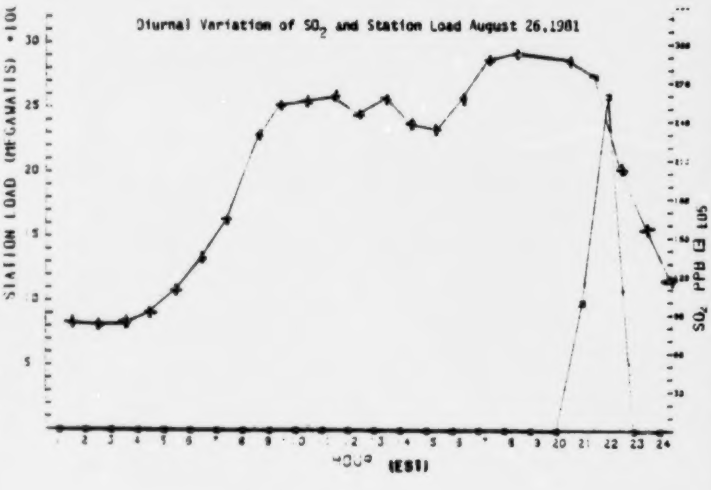


SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 22 AUG 81



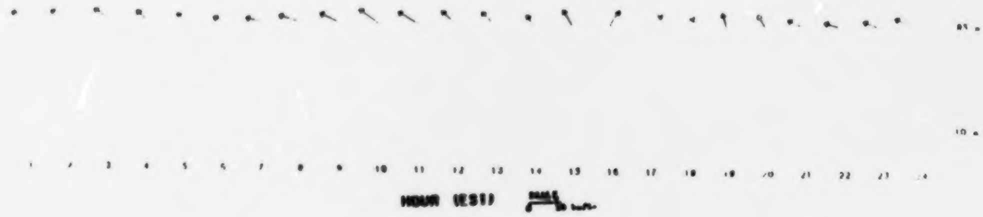
SO$_2$ EPISODE OF AUGUST 26,1981



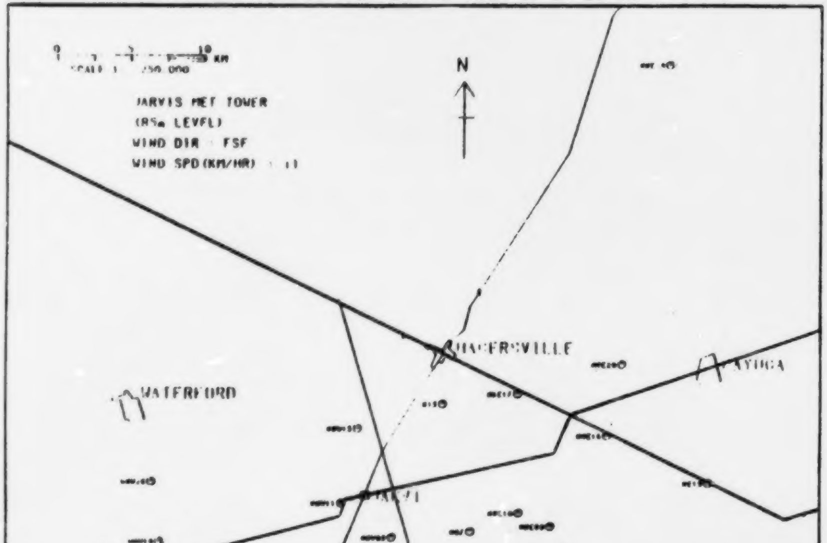


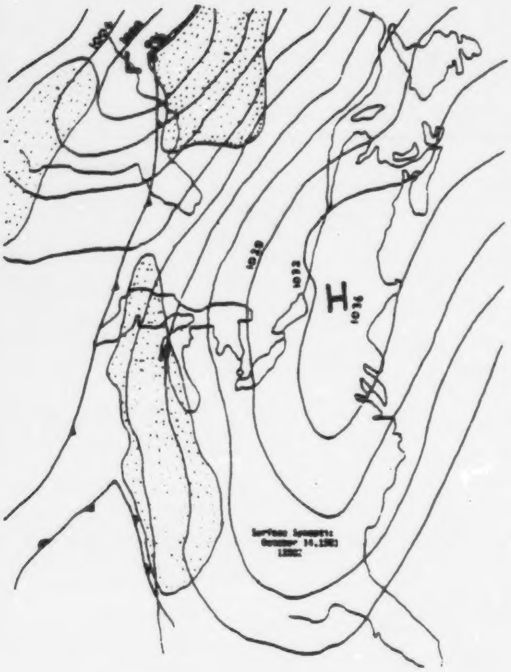
Wind Speed and Direction

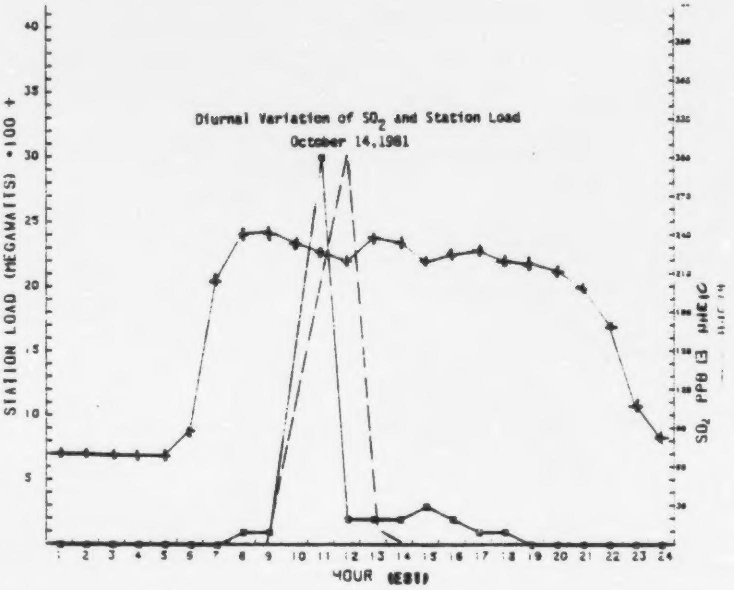
26 AUG 1981

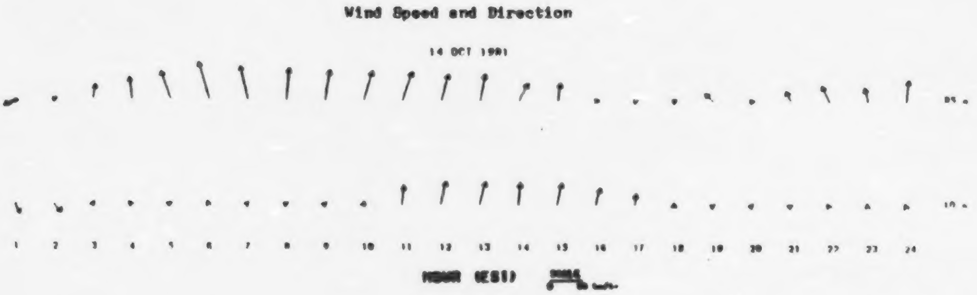


SO2 EXCEEDANCES IN PPB FOR THE HOUR 22 OF 26 AUG 81

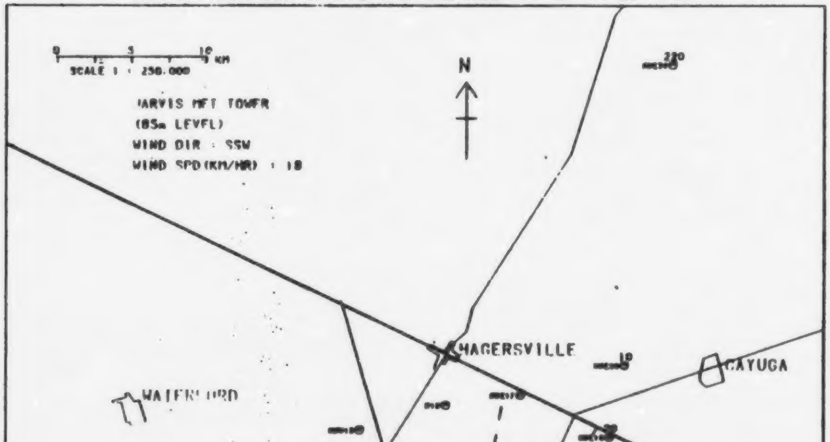




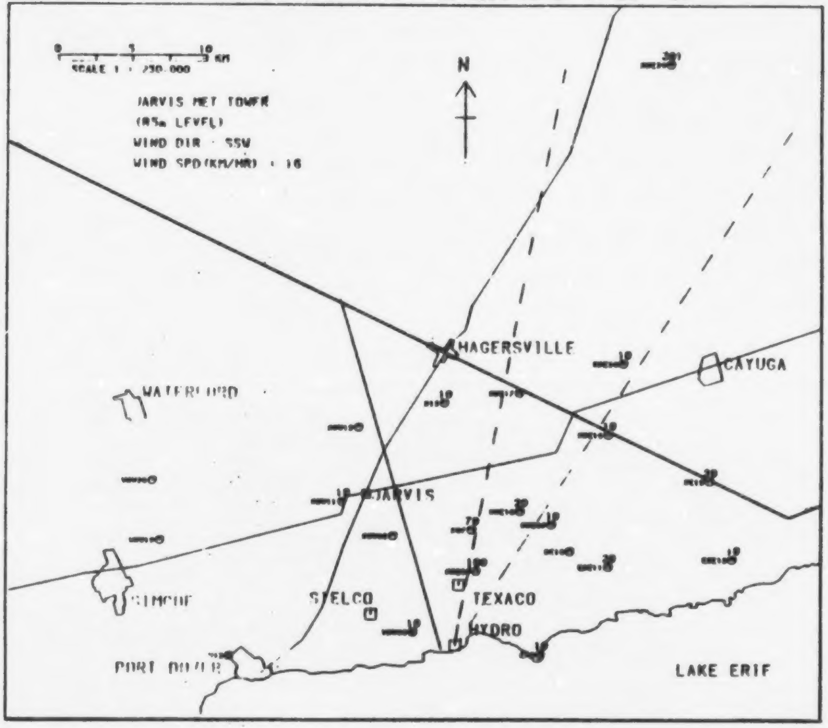




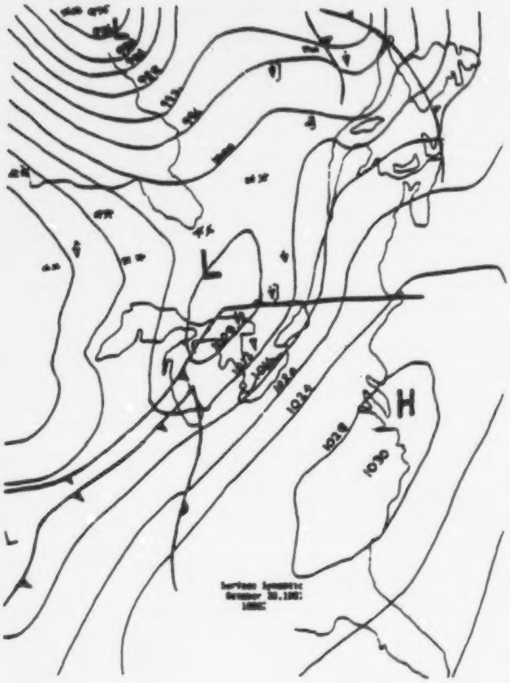
SO2 EXCEEDANCES IN PPB FOR THE HOUR 11 OF 14 OCT 81

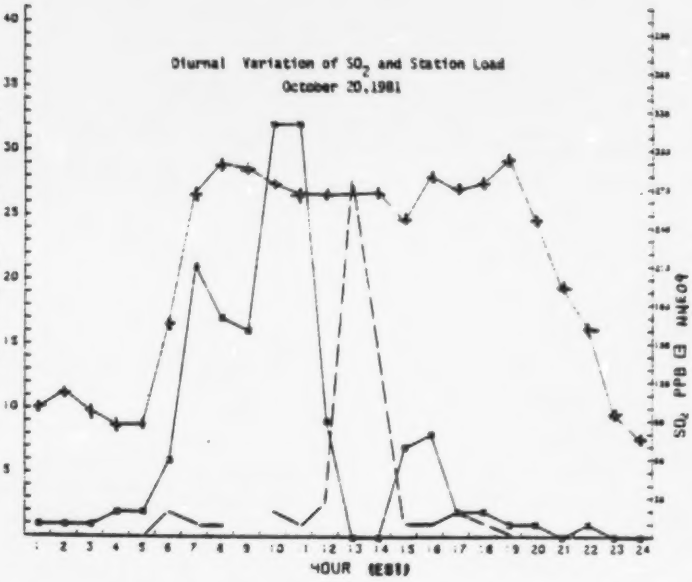


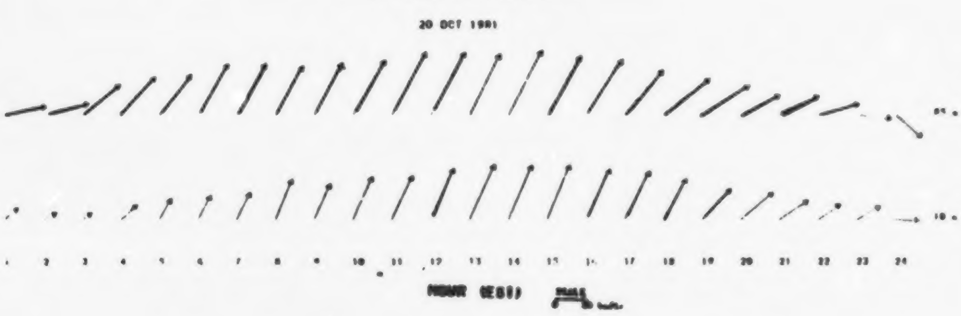
SO_2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 14 OCT 81



SO$_2$ EPISODE OF OCTOBER 20,1981

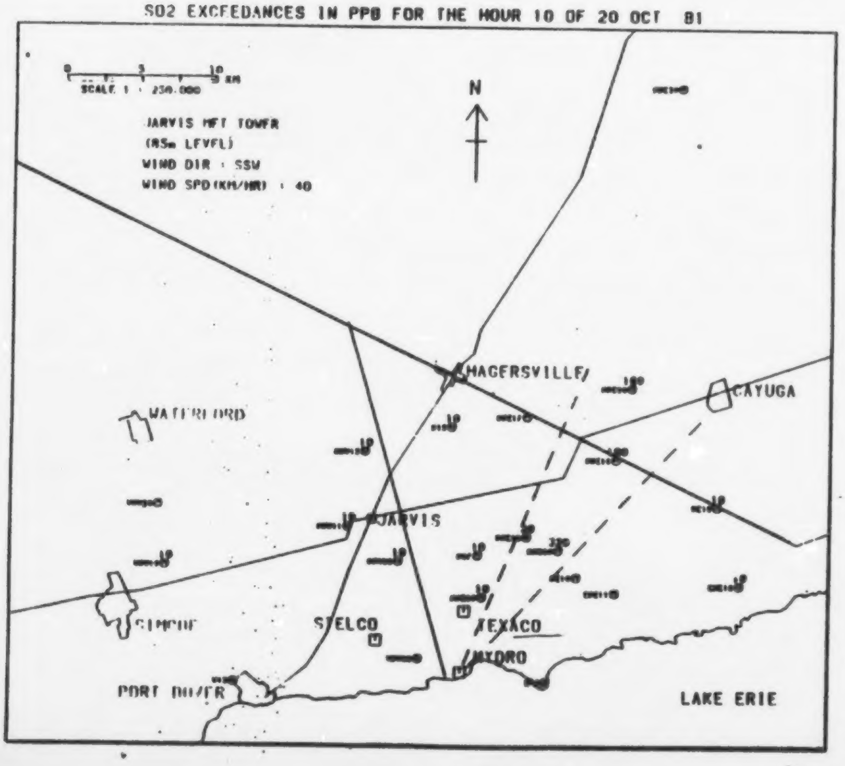




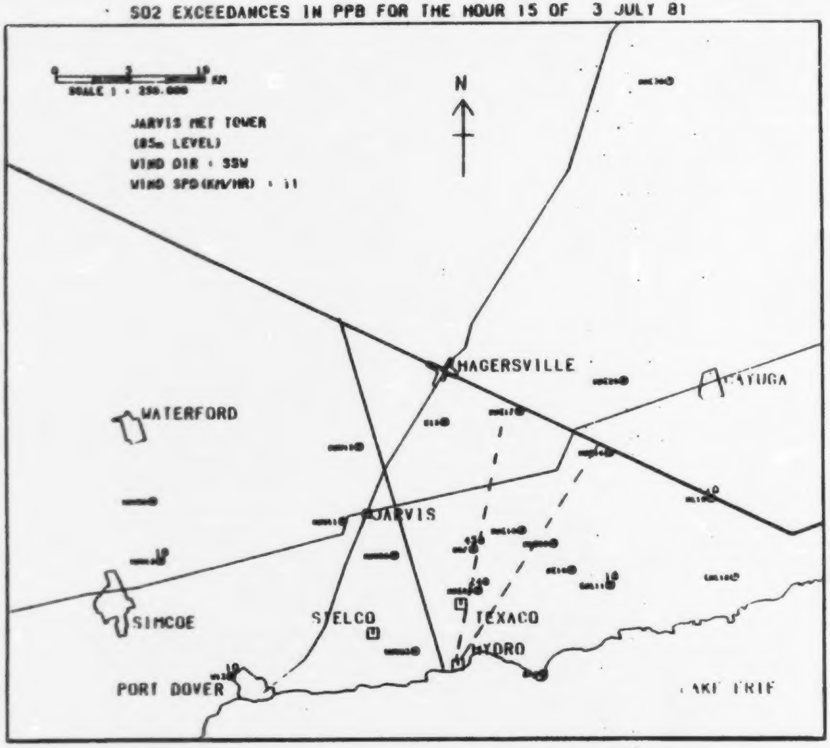

Wind Speed and Direction

20 OCT 1981

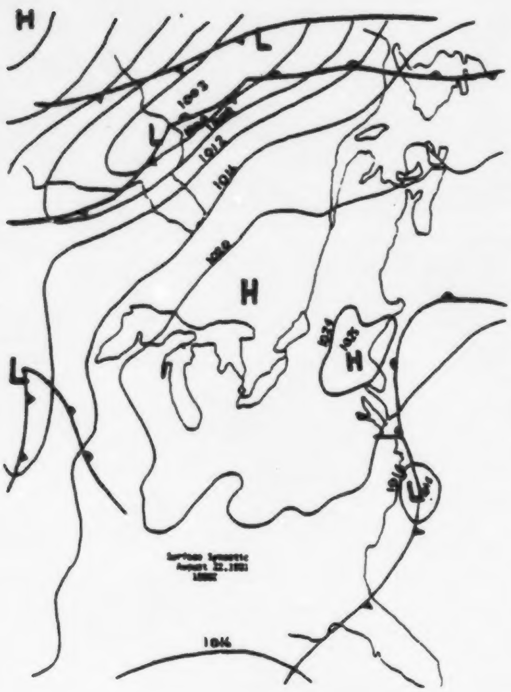
SO2 EXCEEDANCES IN PPB FOR THE HOUR 10 OF 20 OCT 81

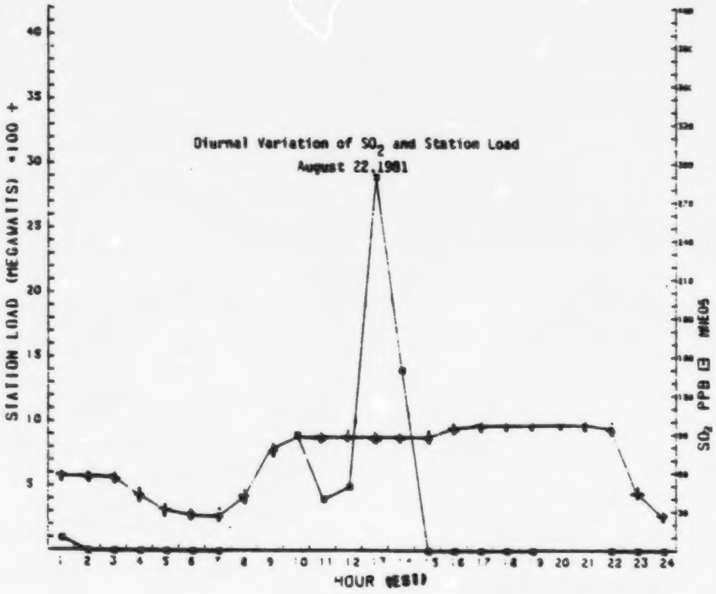


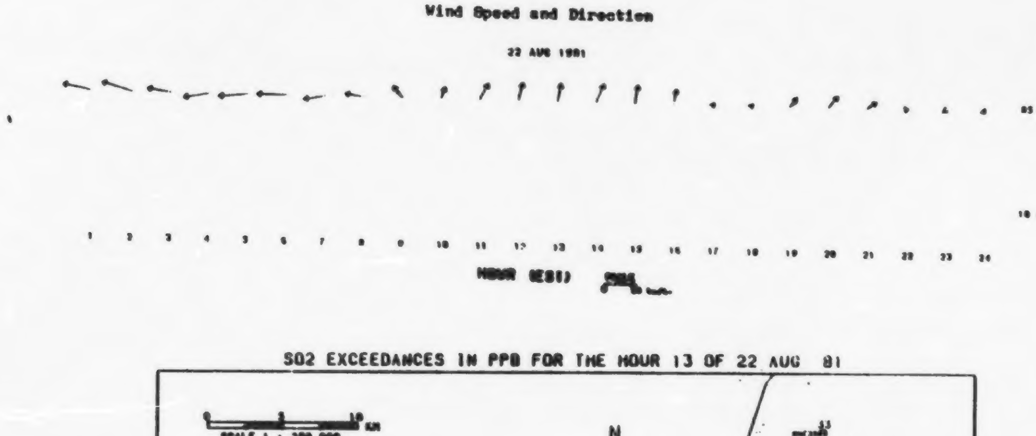
SO_2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 3 JULY 81



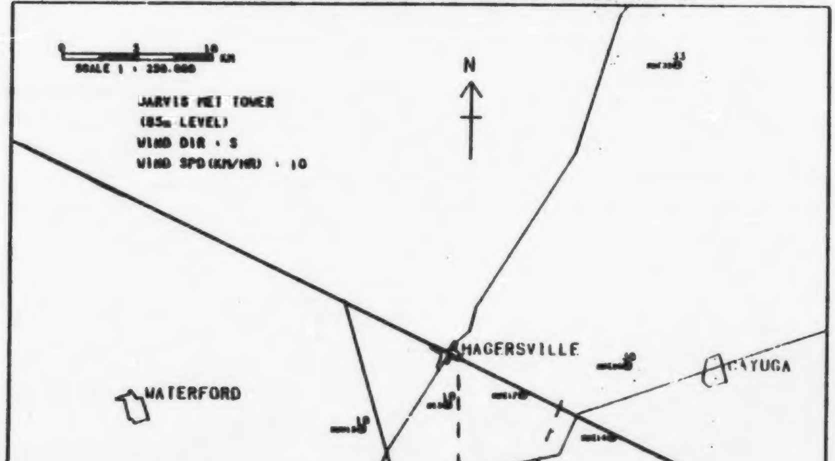
SO_2 EPISODE OF AUGUST 22,1981



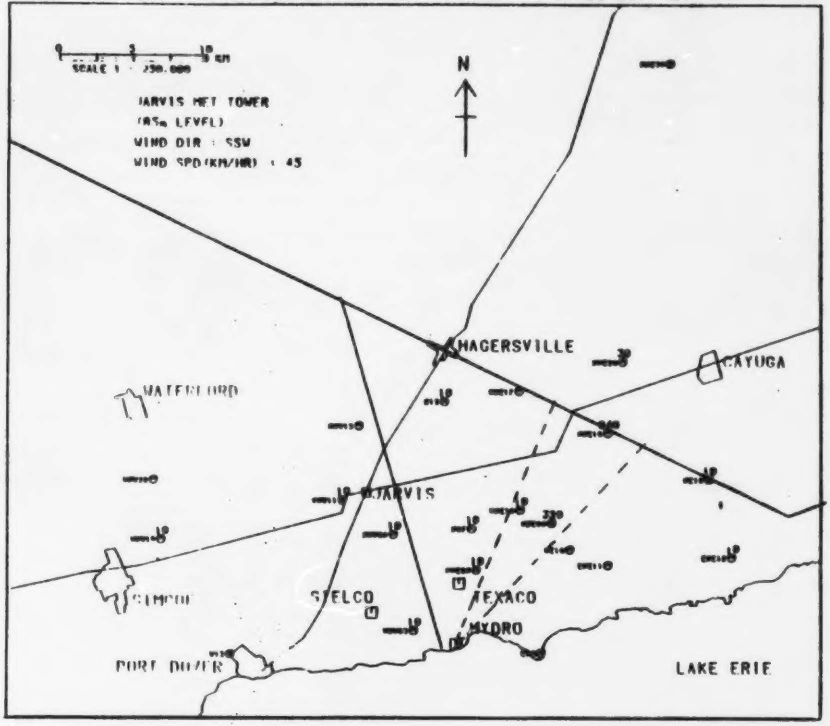




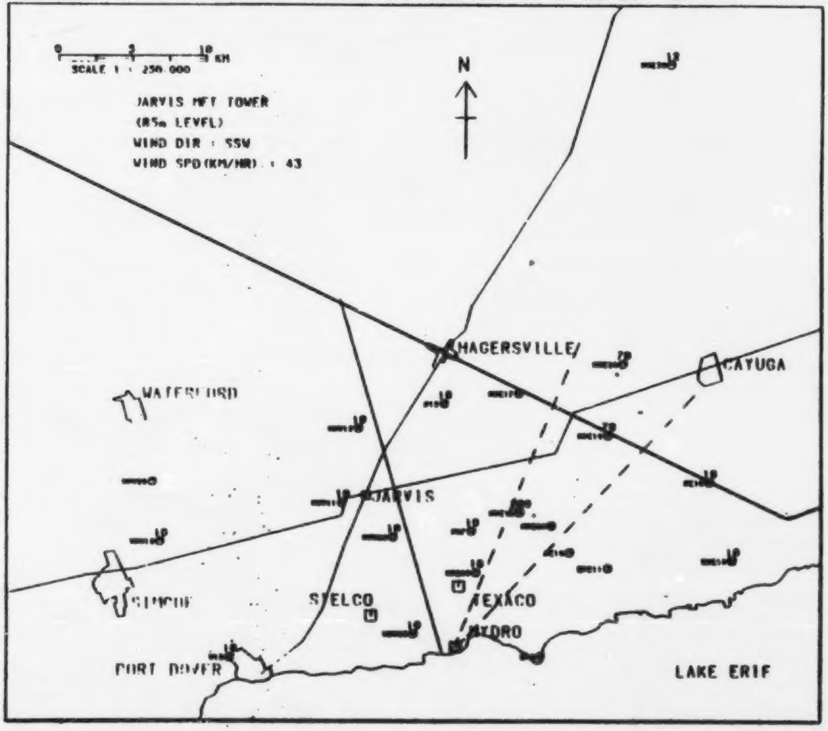
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 22 AUG 81



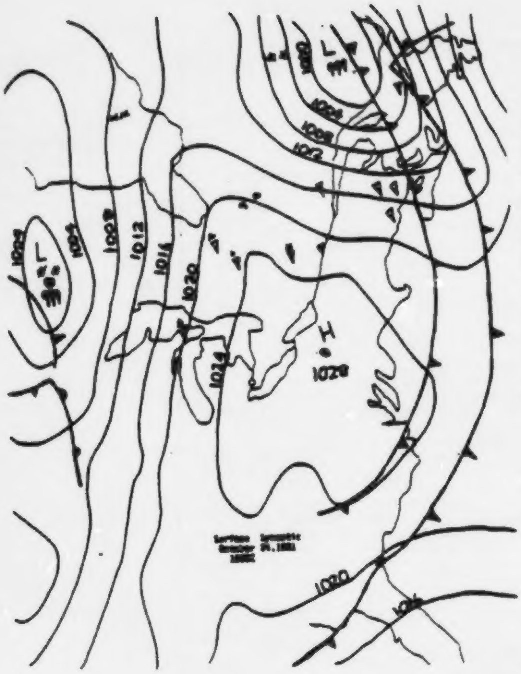
SO2 EXCEEDANCES IN PPB FOR THE HOUR 11 OF 20 OCT 81

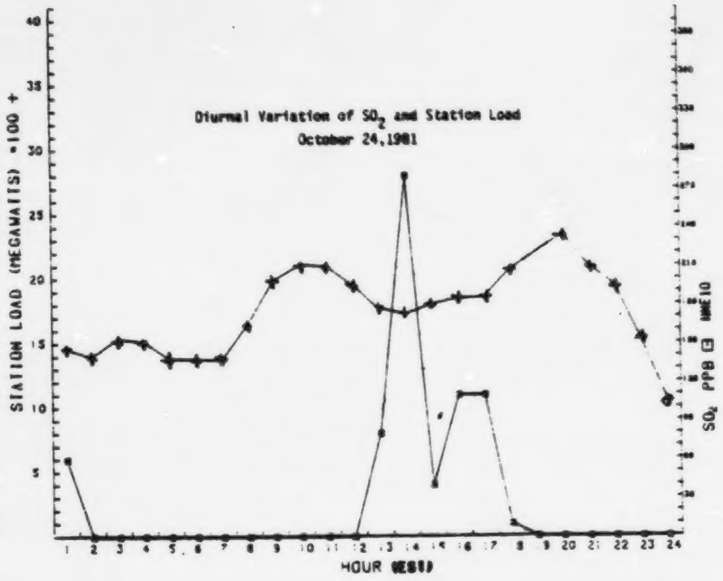


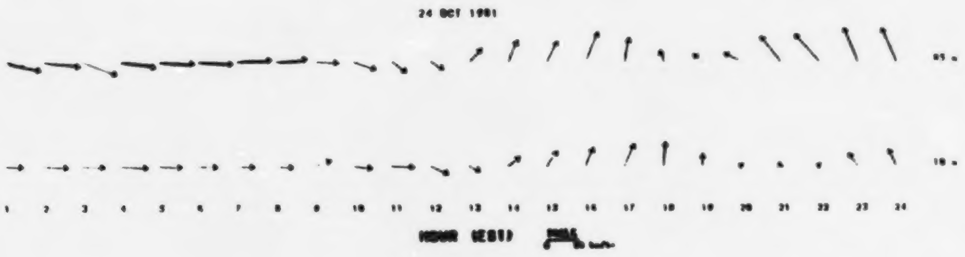
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 20 OCT 81



SO_2 EPISODE OF OCTOBER 24,1981

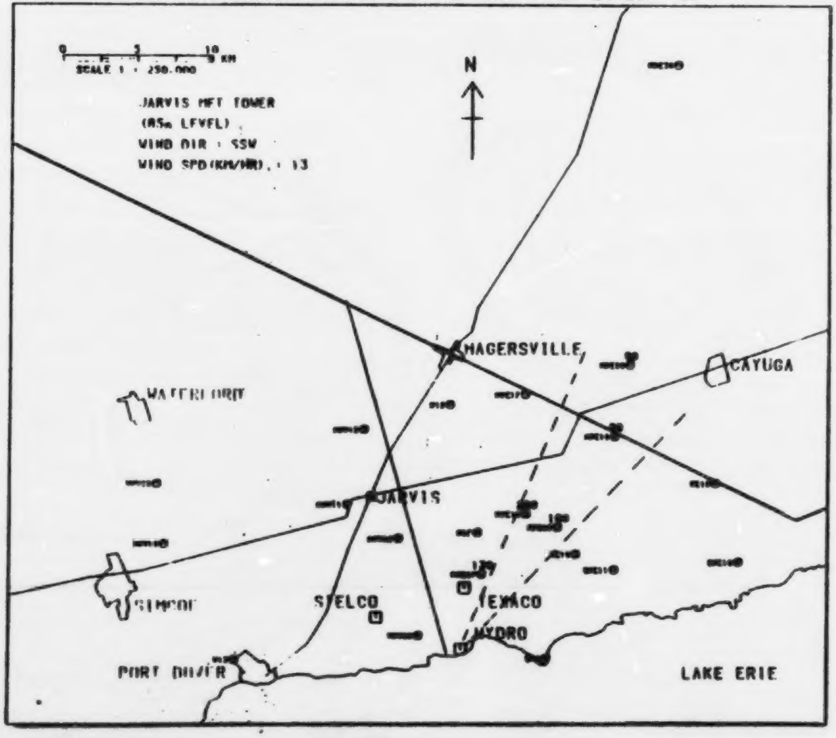




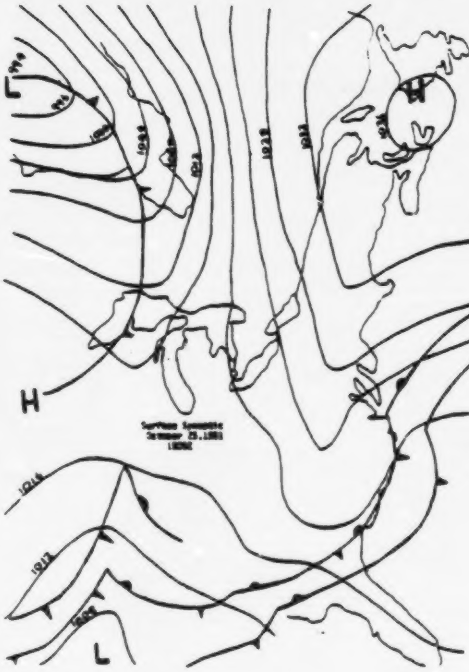


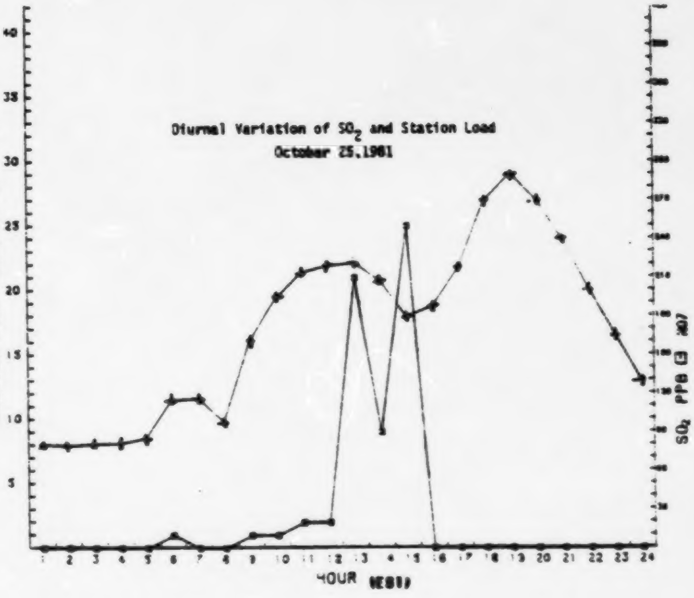
Wind Speed and Direction

SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 24 OCT 81

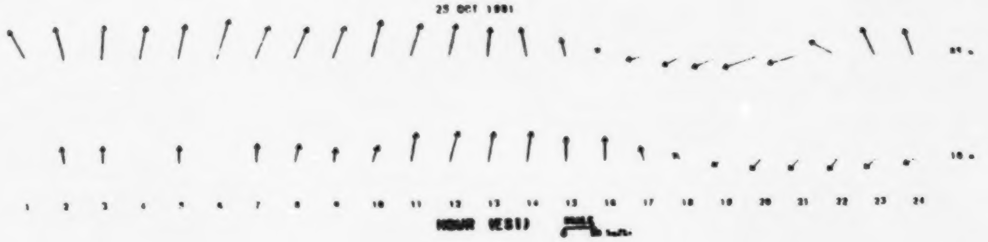


SO_2 EPISODE OF OCTOBER 25,1981

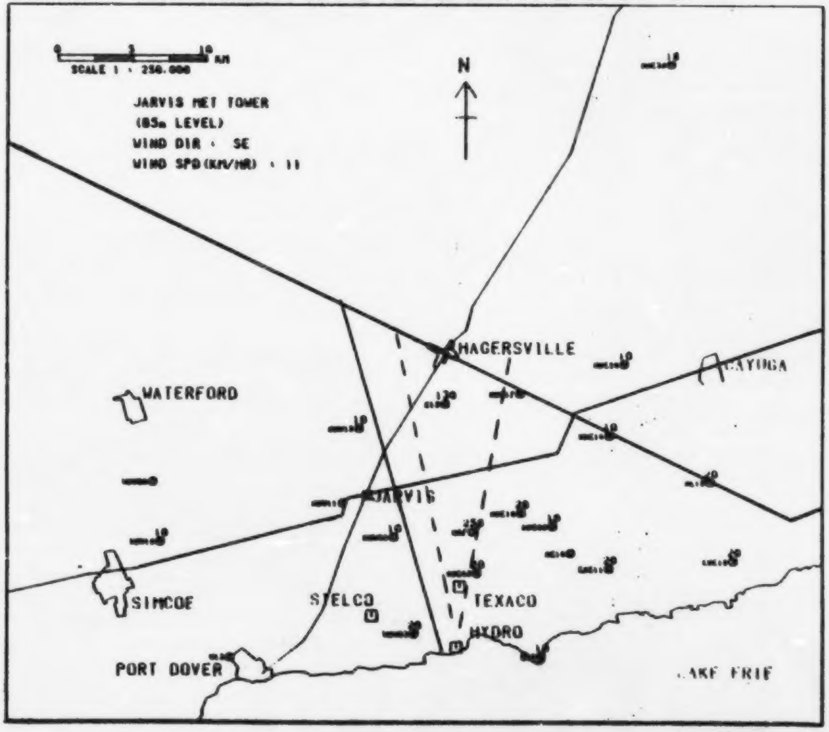




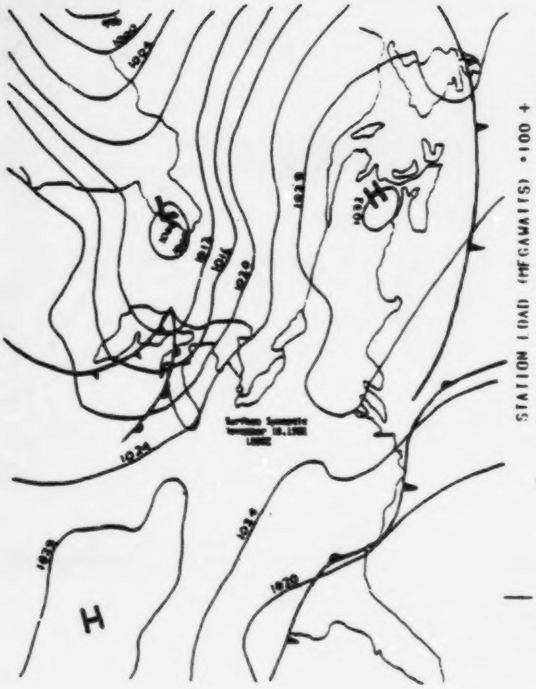
Wind Speed and Direction

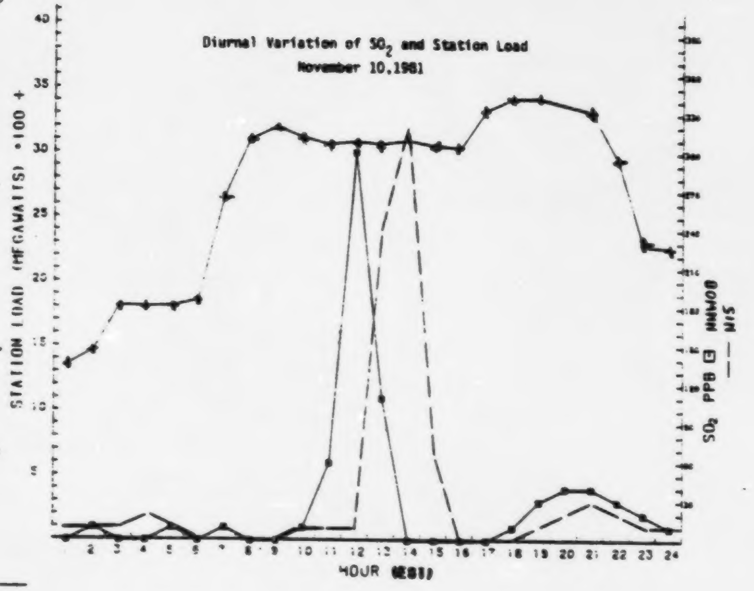


SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 25 OCT 81

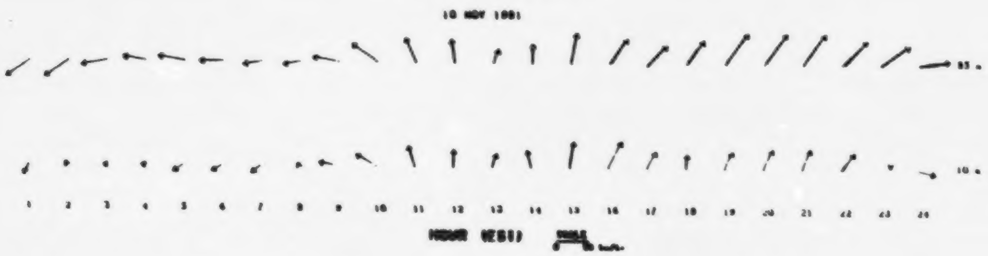


SO$_2$ EPISODE OF NOVEMBER 10,1981

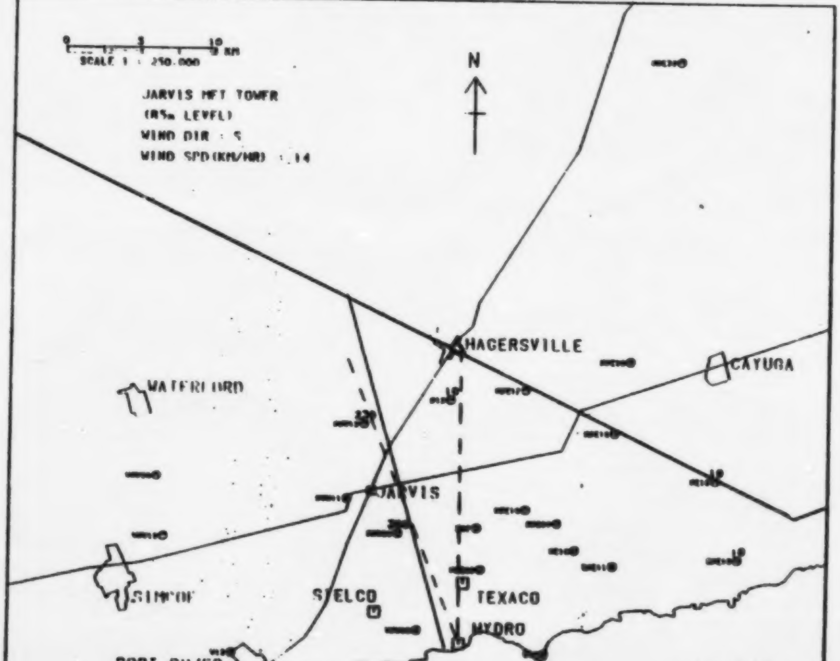




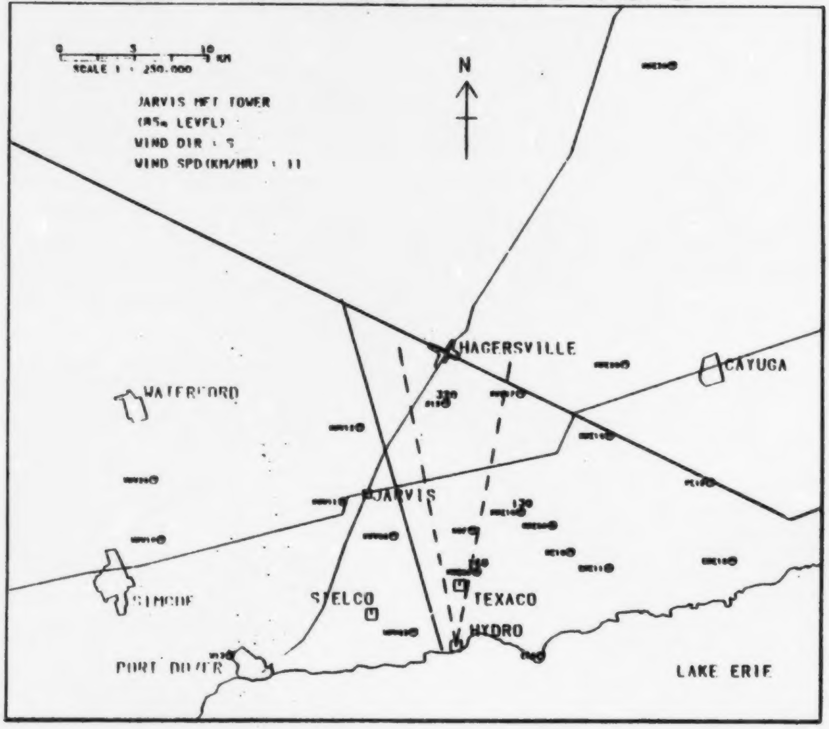
Wind Speed and Direction



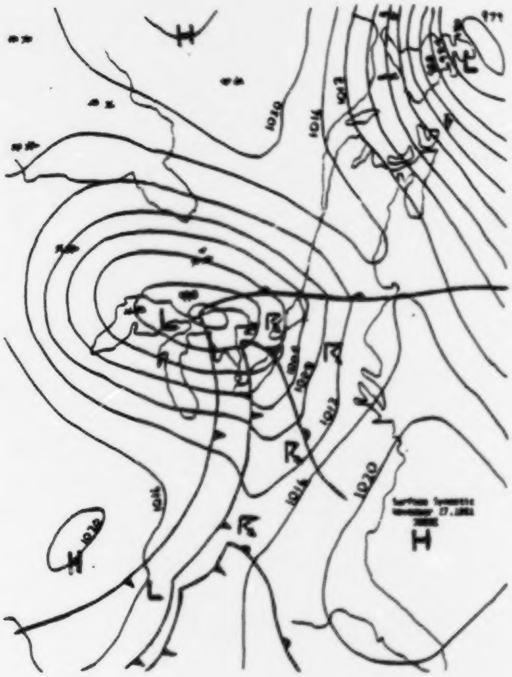
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 10 NOV 81

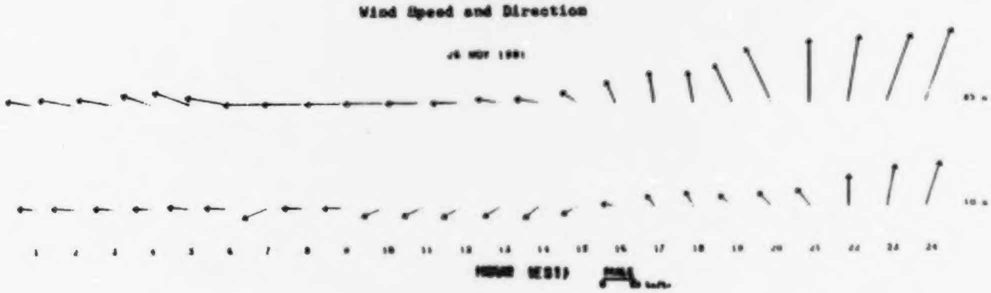


SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 10 NOV 81

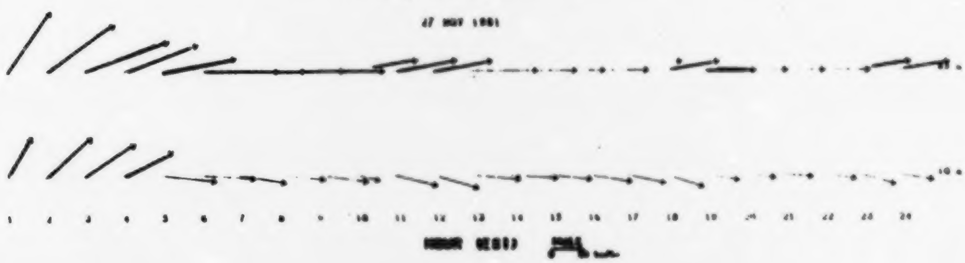


SO_2 EPISODE OF NOVEMBER 26 and 27,1981

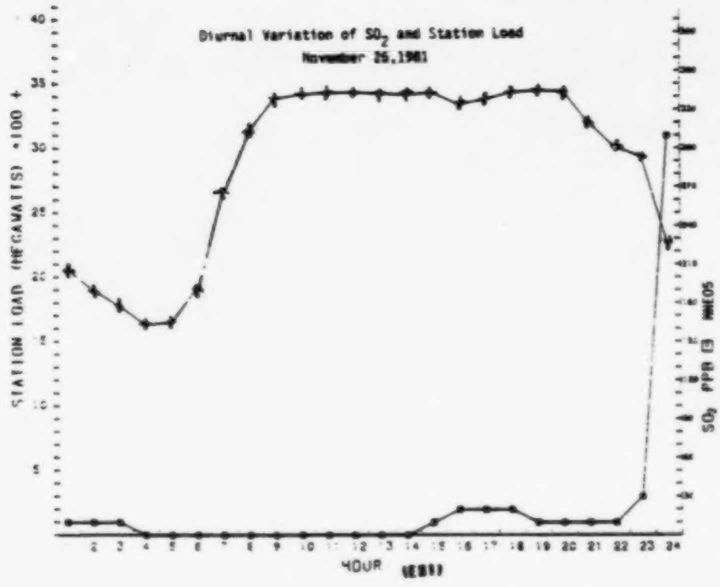


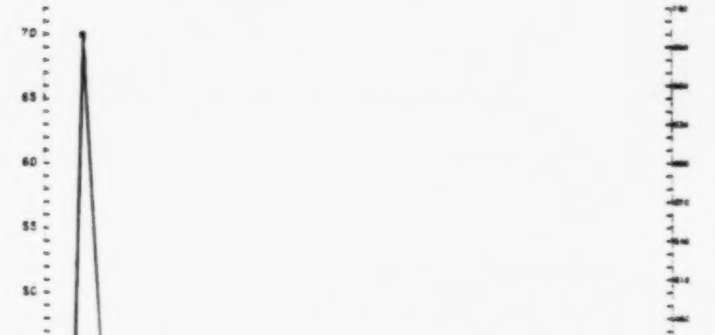

Wind Speed and Direction

26 NOV 1981

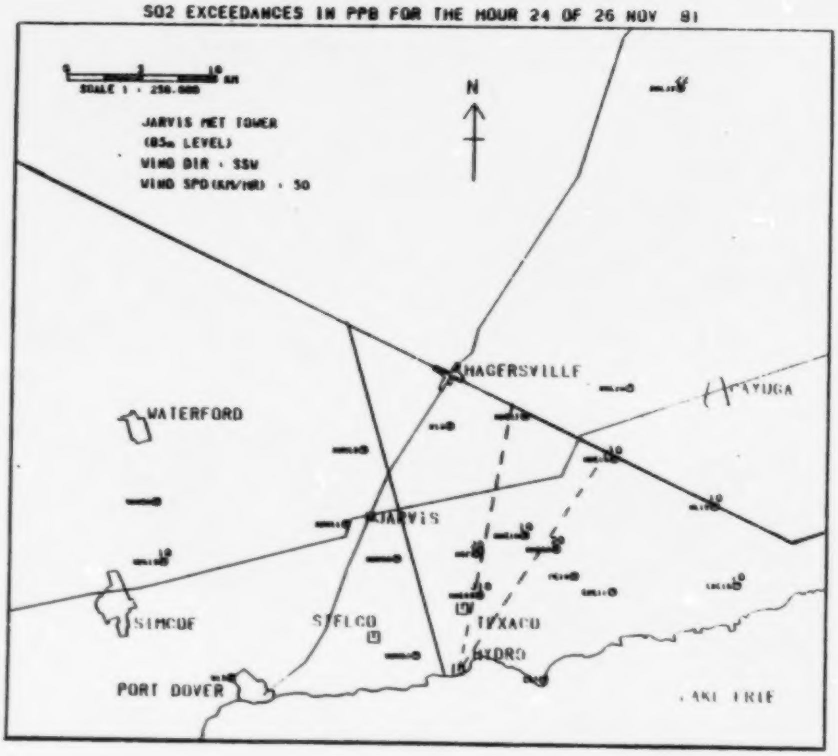

Wind Speed and Direction

27 NOV 1981

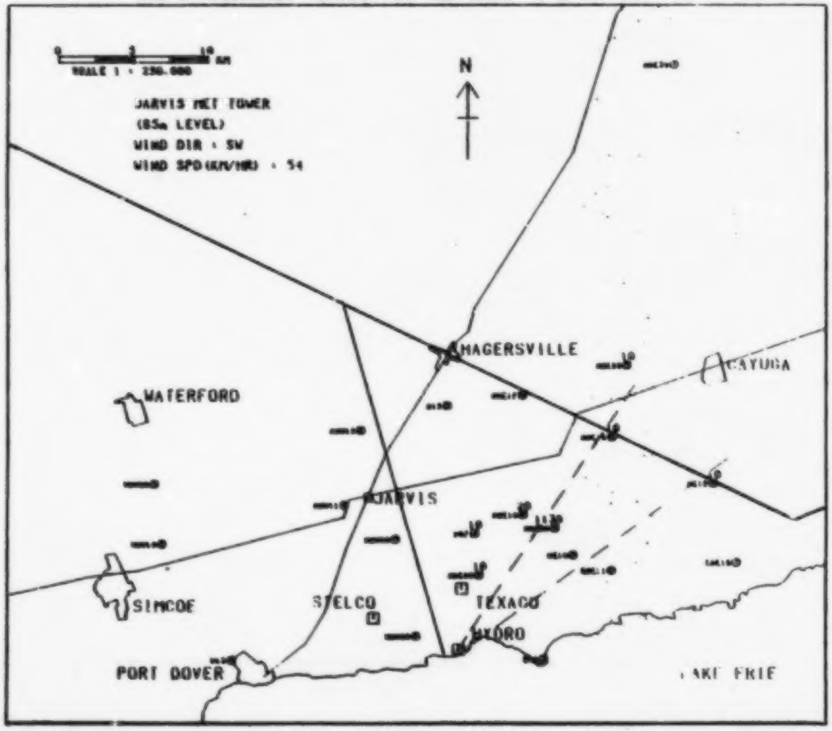

Diurnal Variation of SO_2 and Station Load
November 26,1981


Diurnal Variation of SO_2 and Station Load
November 27,1981

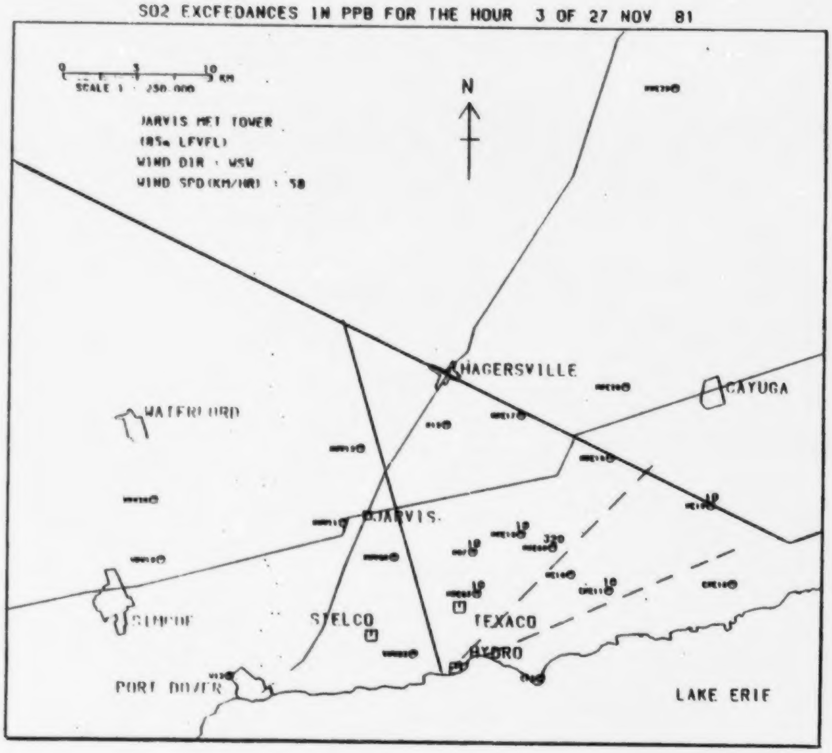
SO2 EXCEEDANCES IN PPB FOR THE HOUR 24 OF 26 NOV 81

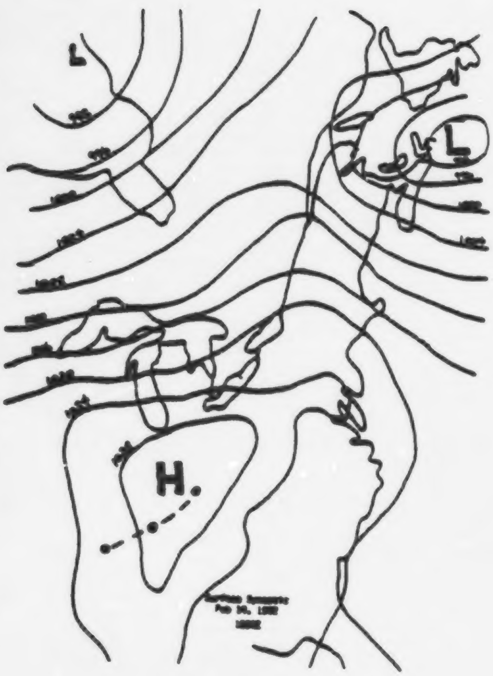


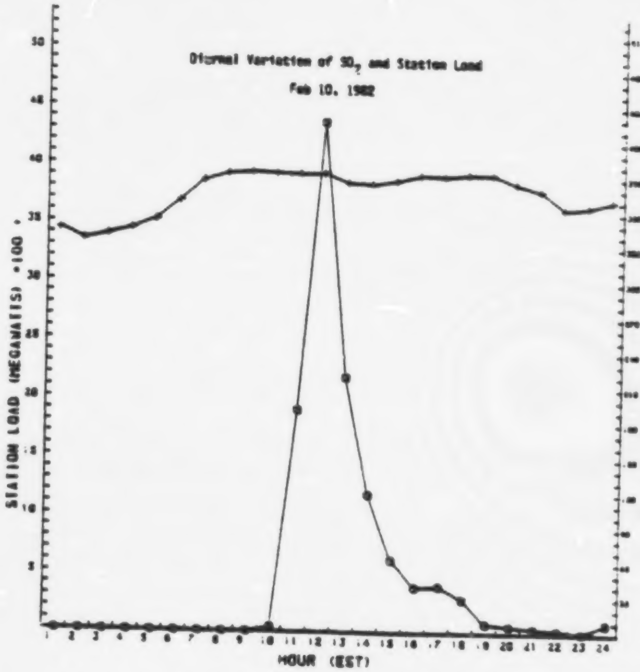
SO2 EXCEEDANCES IN PPB FOR THE HOUR 2 OF 27 NOV 81

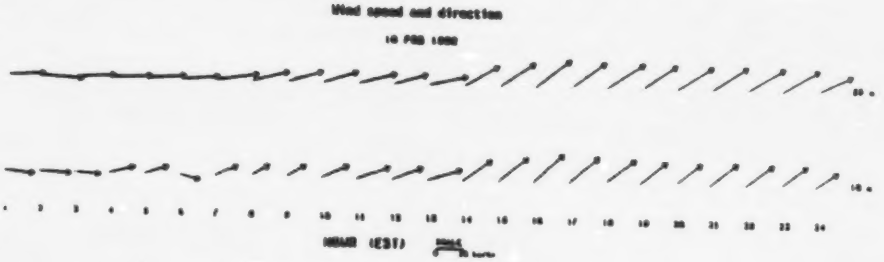


SO2 EXCFEDANCES IN PPB FOR THE HOUR 3 OF 27 NOV 81

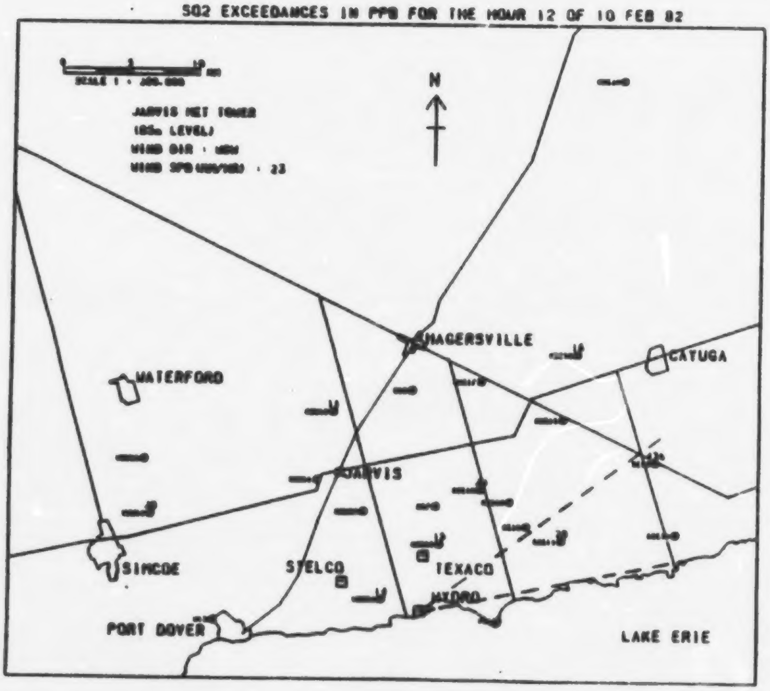




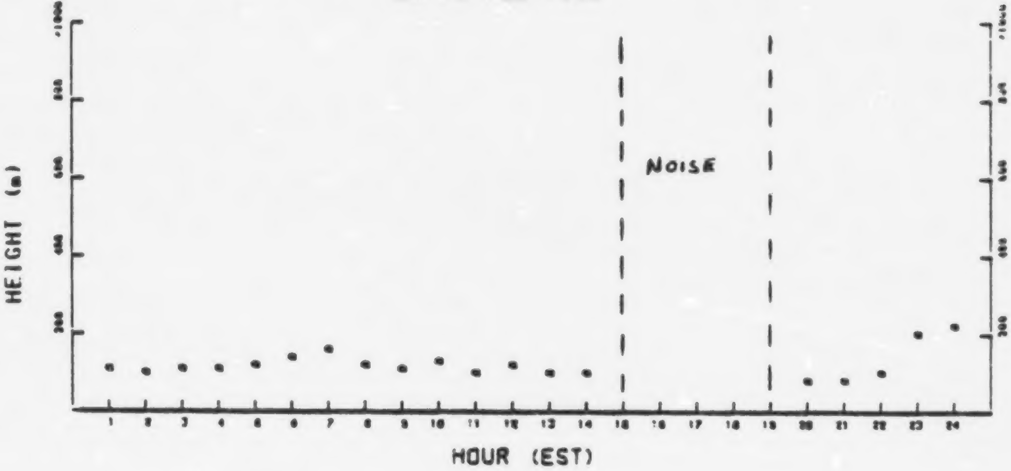




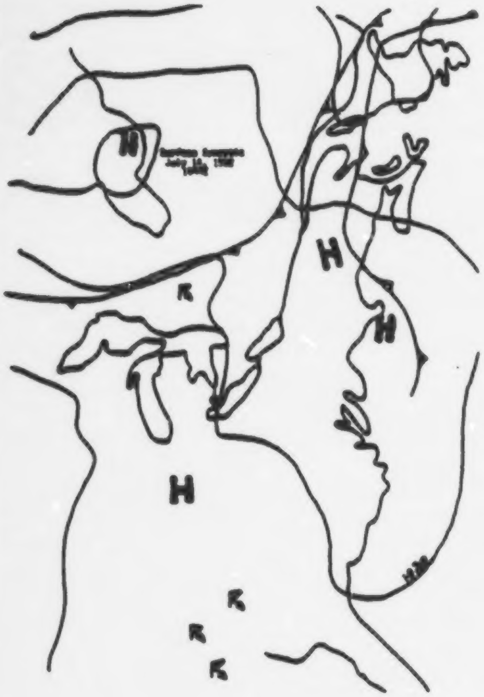
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 10 FEB 82

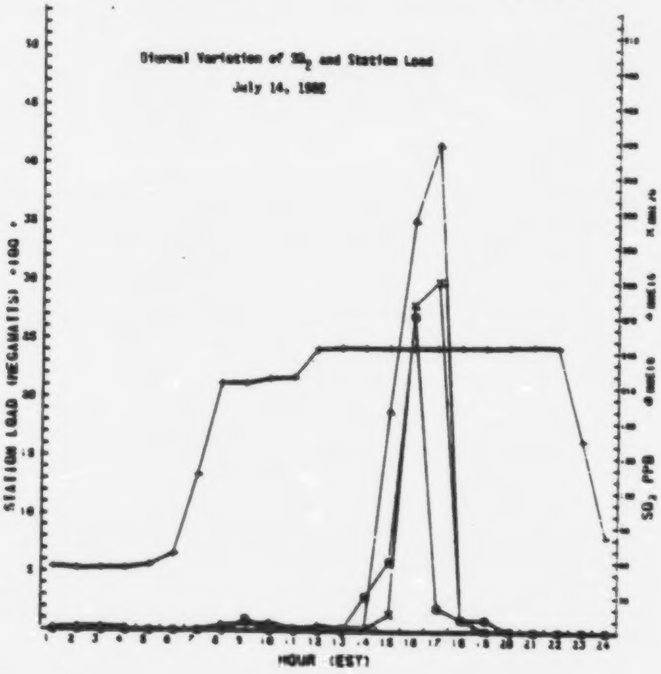


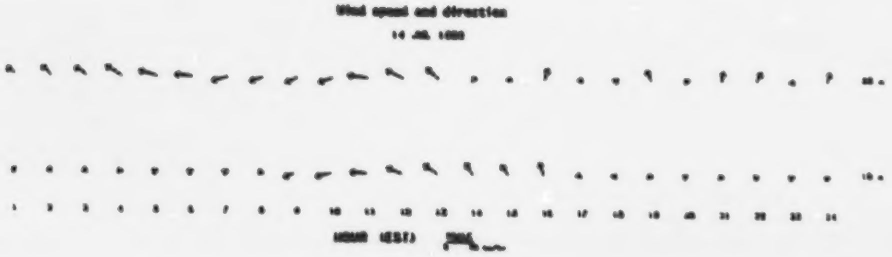
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 10 FEB 1982

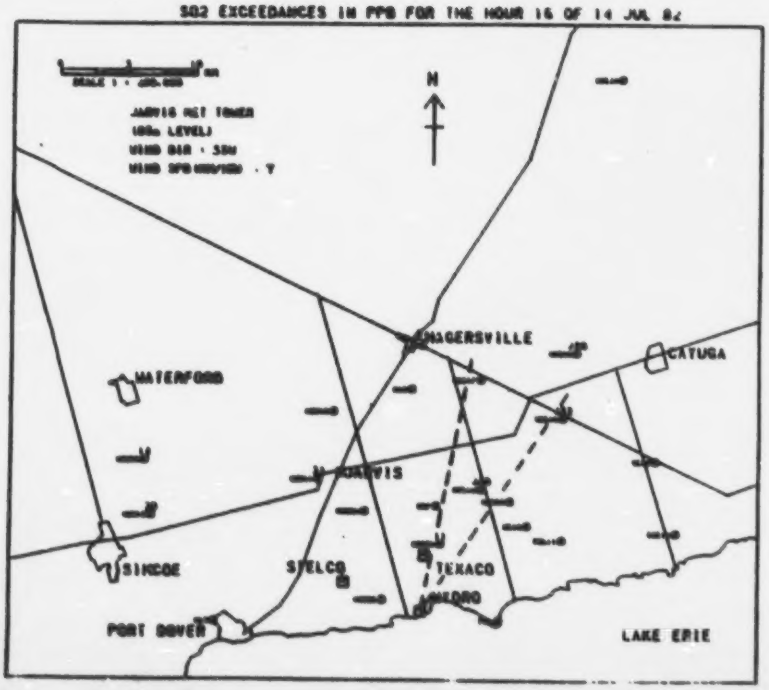


SO_2 EPISODE OF JULY 14,1982

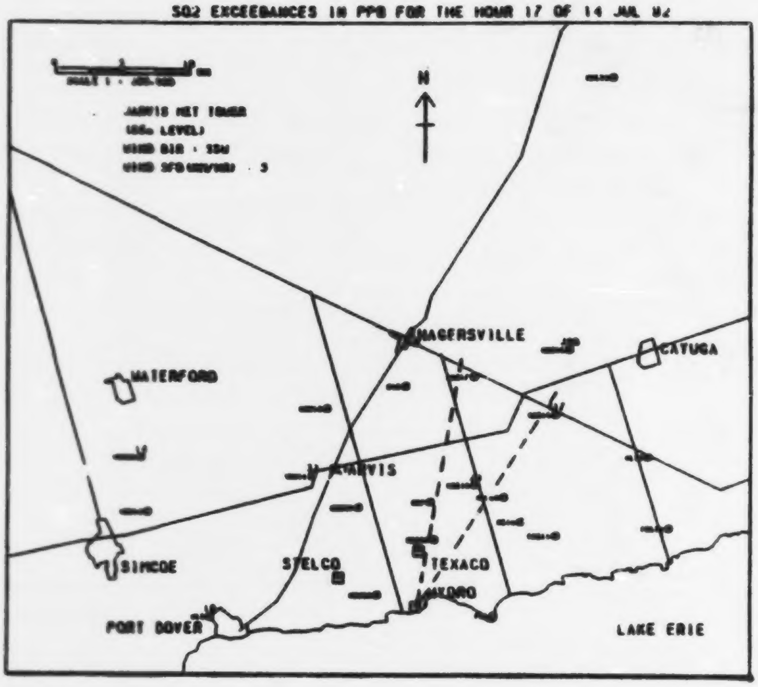




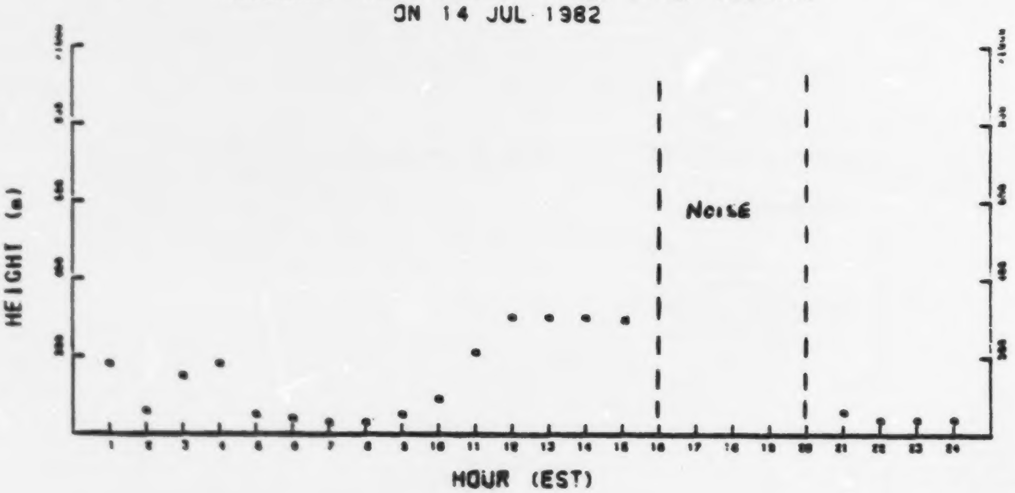


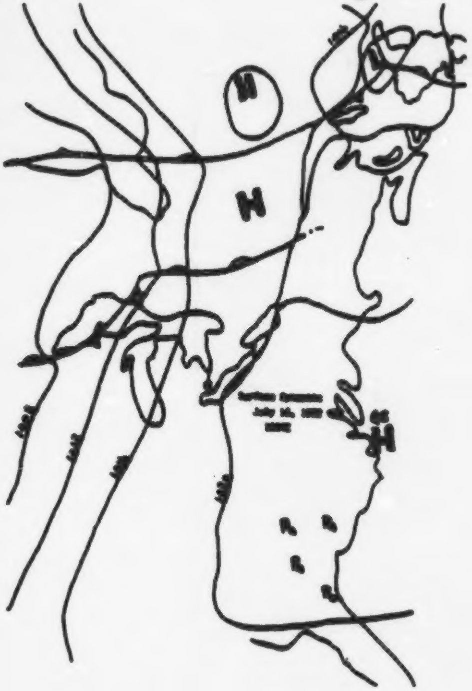


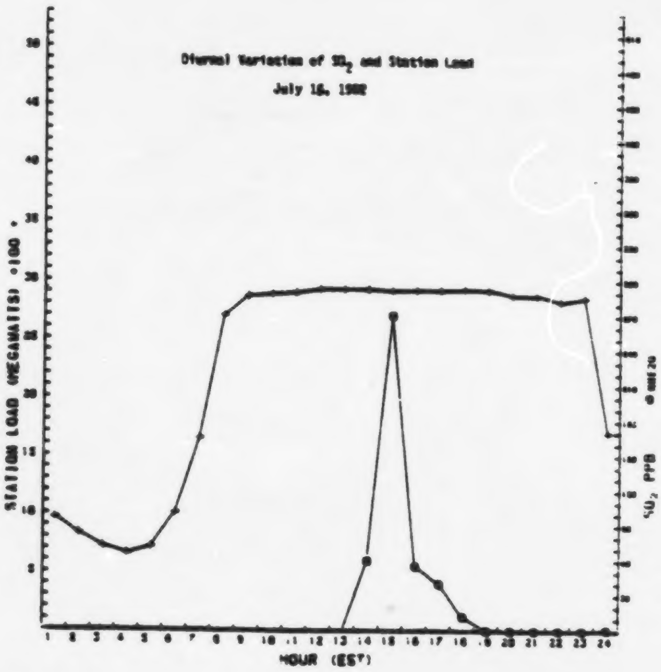
SO2 EXCEEDANCES IN PPB FOR THE HOUR 17 OF 14 JUL 82

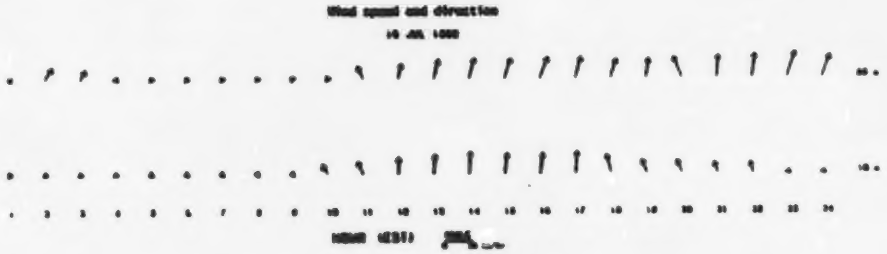


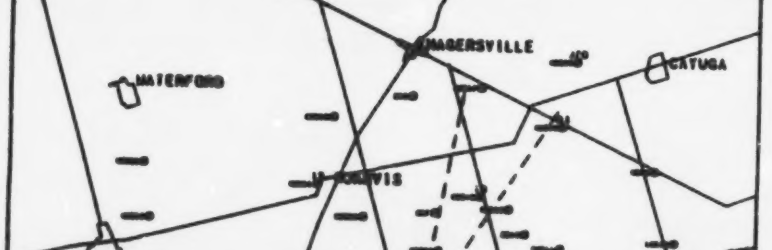
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 14 JUL 1982



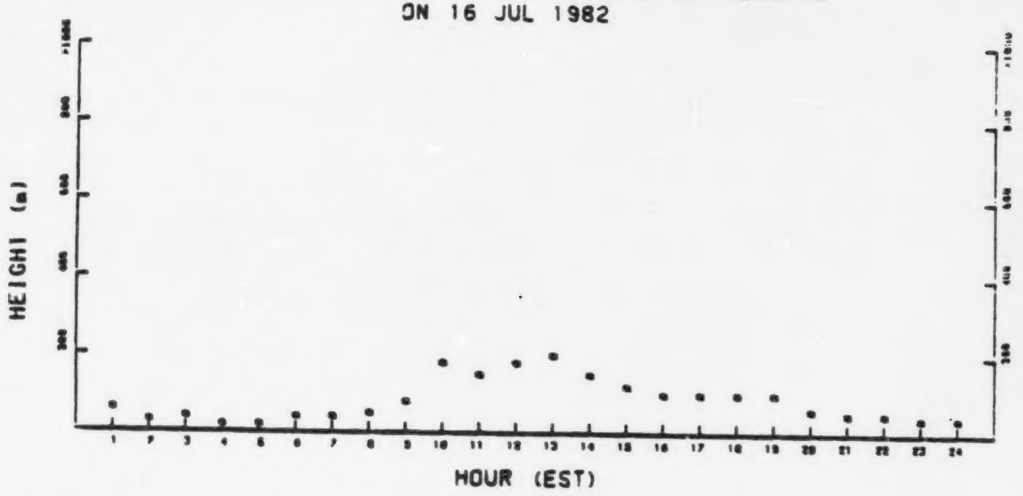




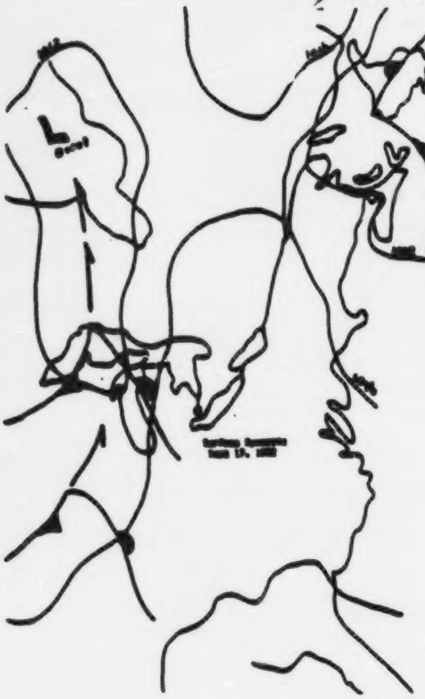


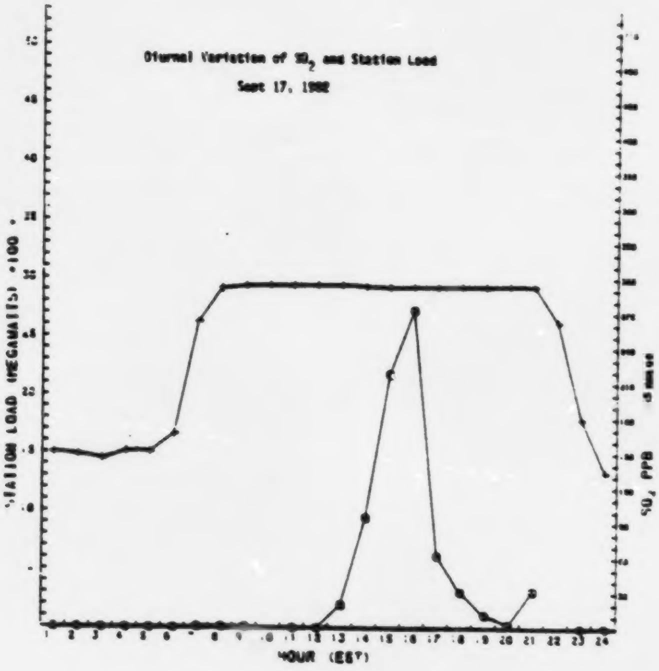

SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 16 JUL 82

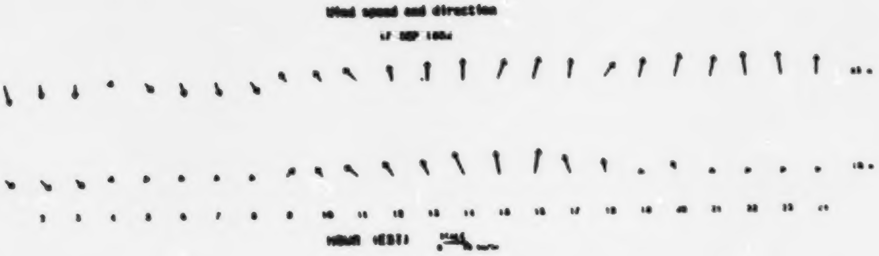
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 16 JUL 1982



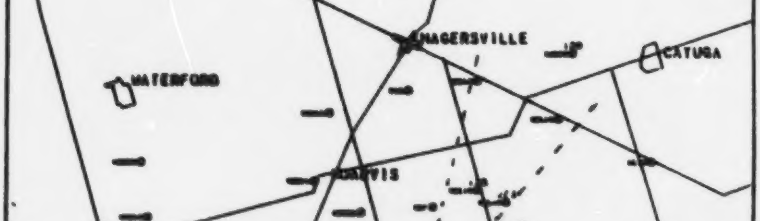
SO_2 EPISODE OF SEPTEMBER 17,1982



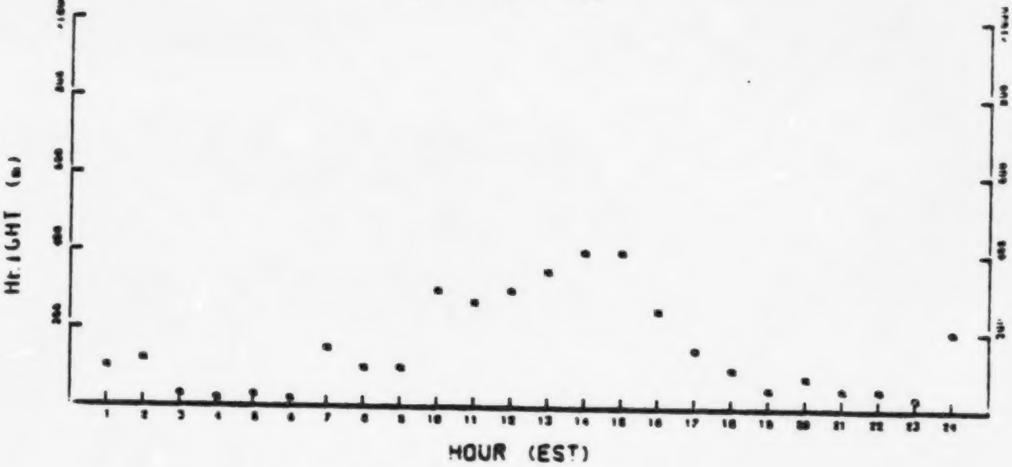




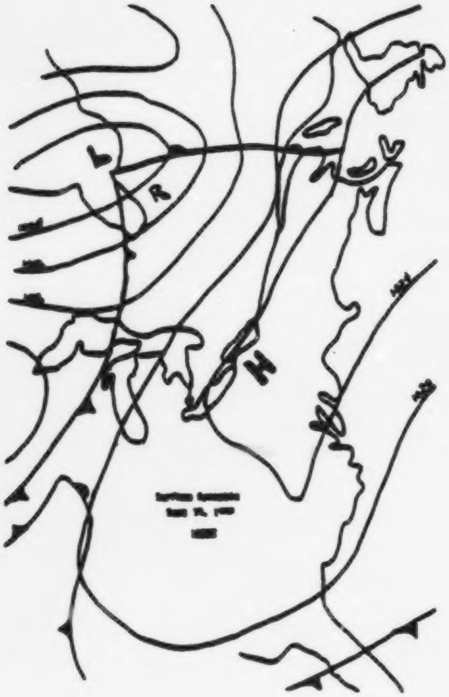
SO2 EXCEEDANCES IN PPB FOR THE HOUR 16 OF 17 SEP 82

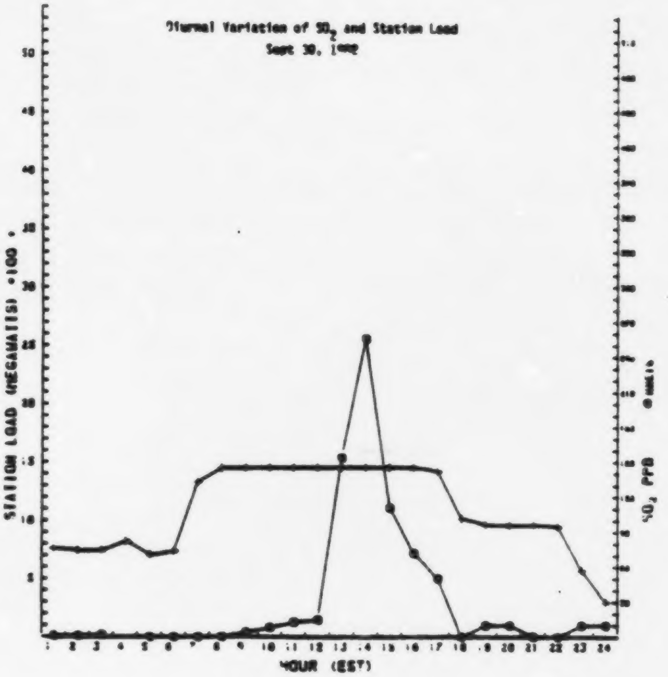


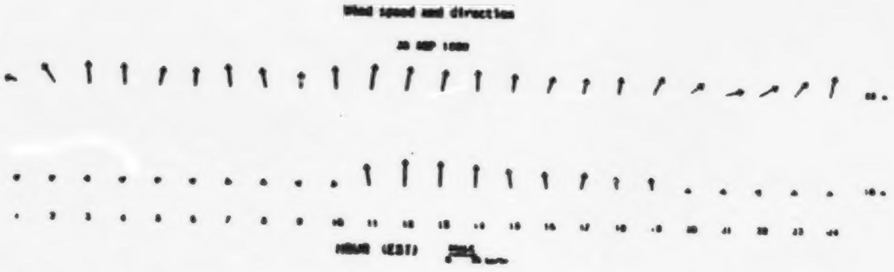
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 17 SEP 1982



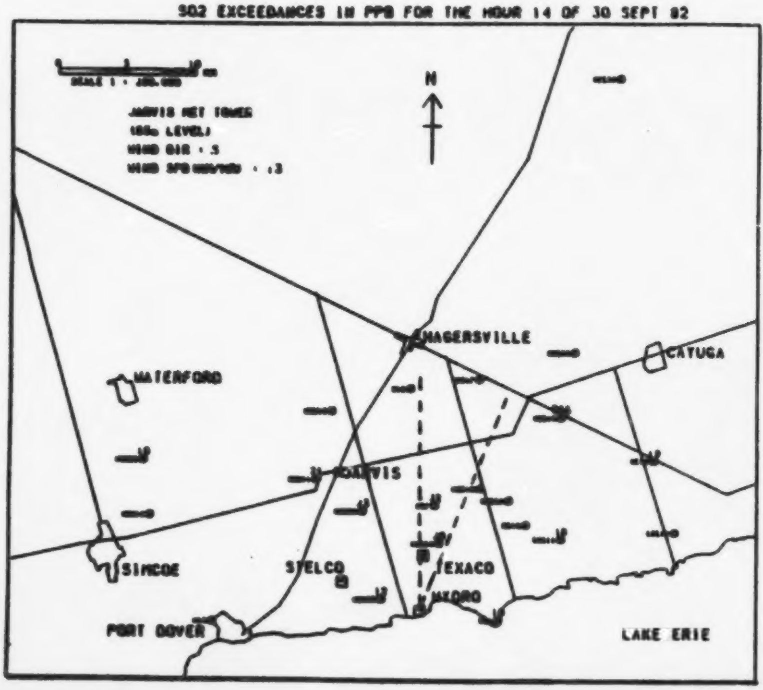
SO$_2$ EPISODE OF SEPTEMBER 30,1982

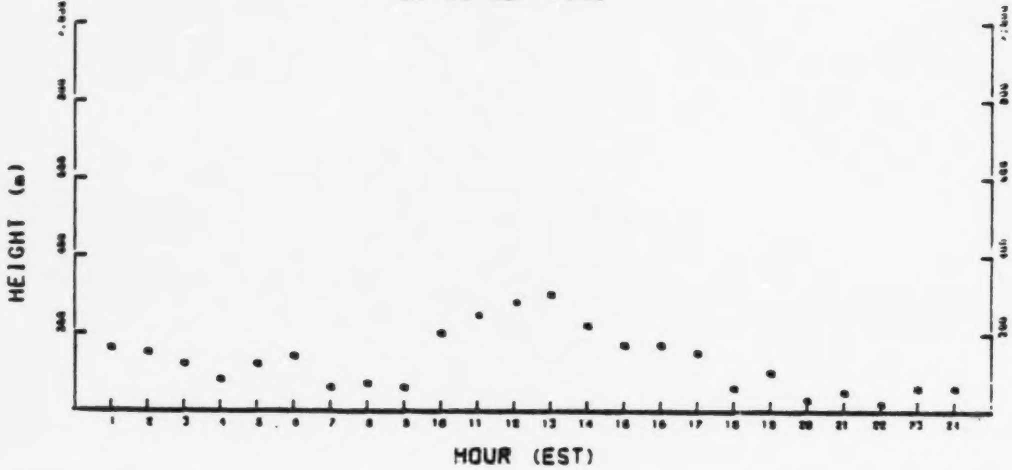




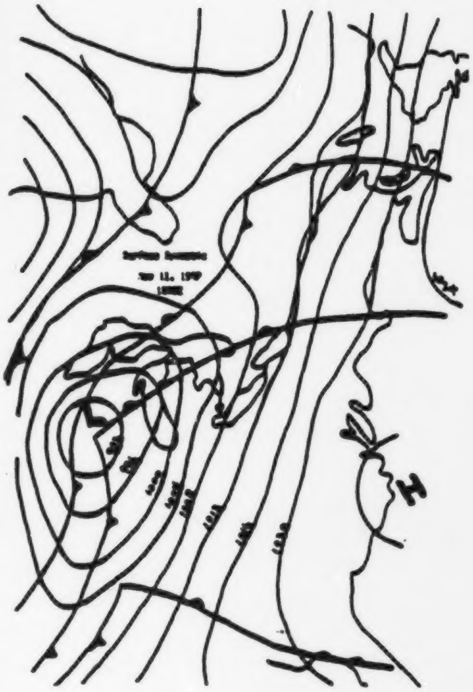


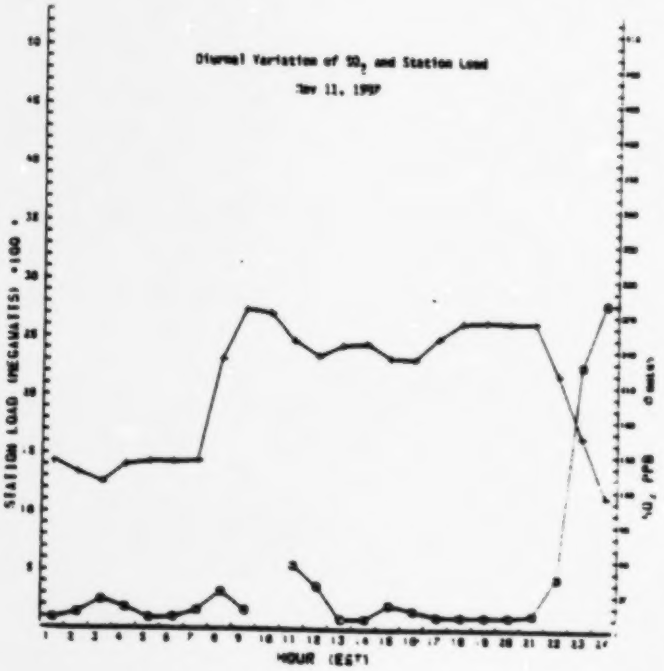
SO2 EXCEEDANCES IN PPB FOR THE HOUR 14 OF 30 SEPT 82

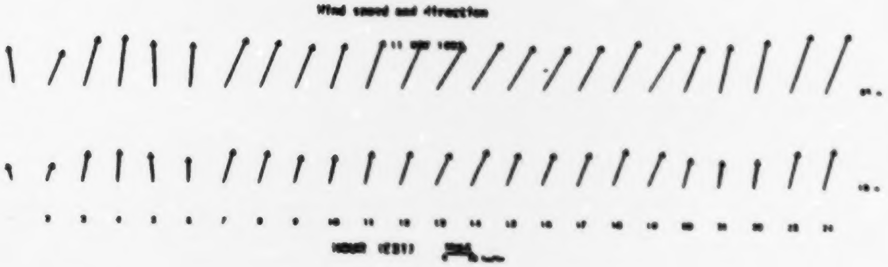




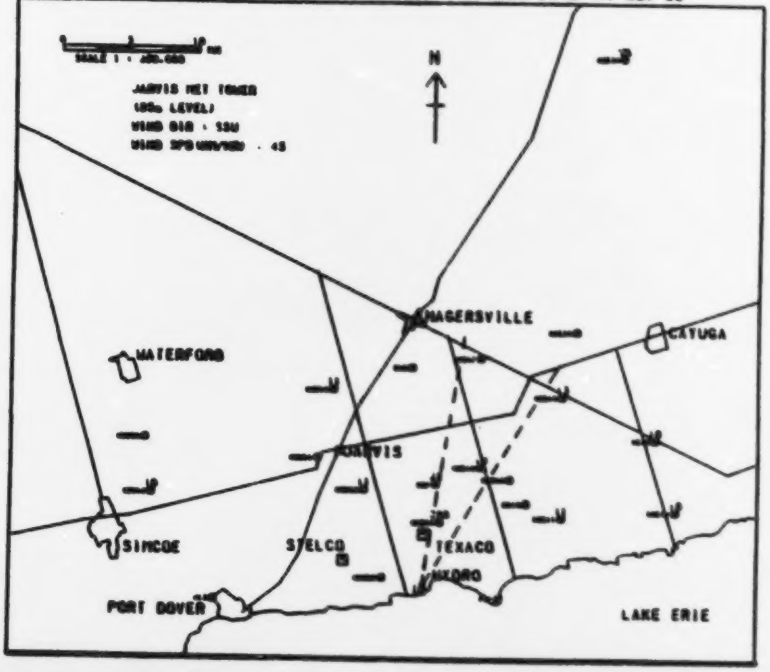
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 30 SEP 1982



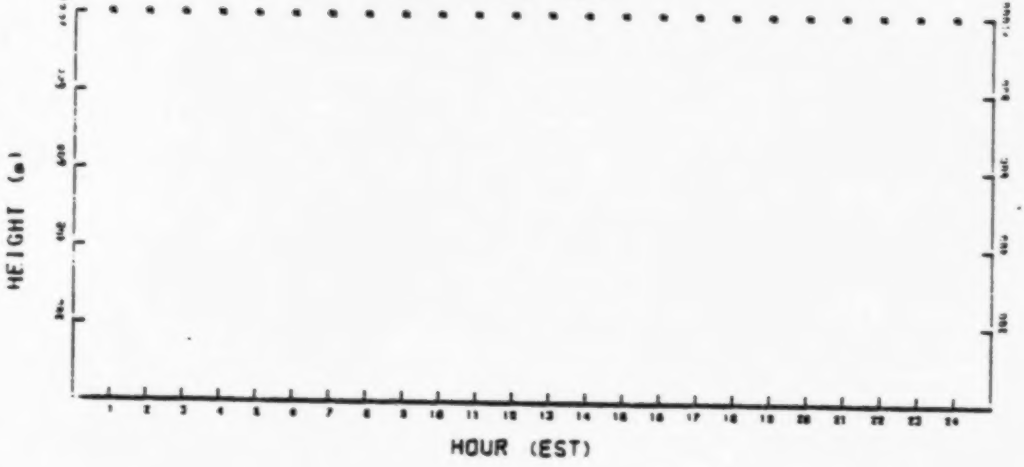




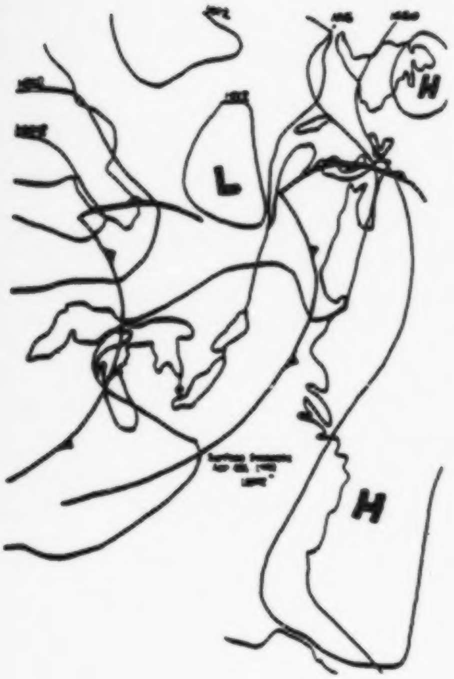
SO2 EXCEEDANCES IN PPB FOR THE HOUR 24 OF 11 NOV 82

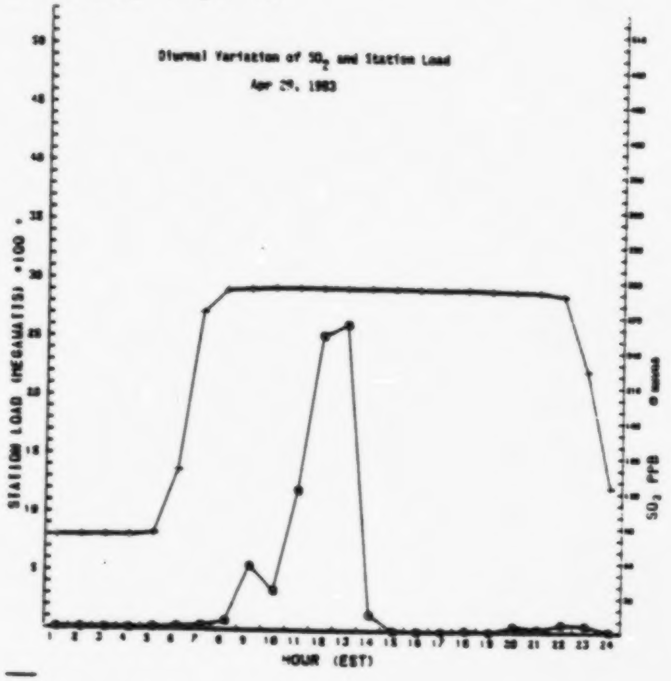


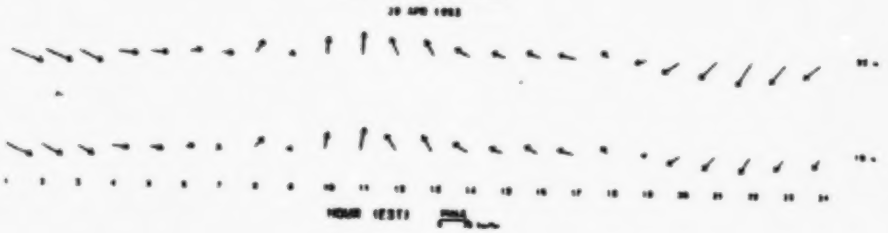
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 11 NOV 1982



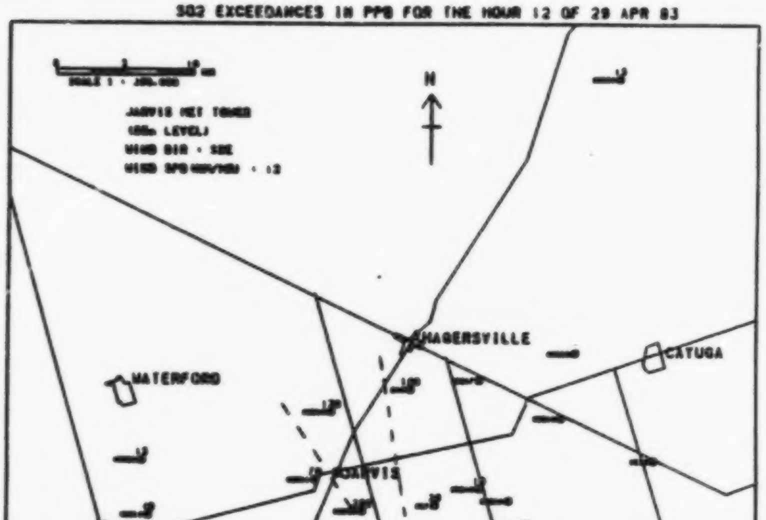
SO$_2$ EPISODE OF APRIL 29,1983



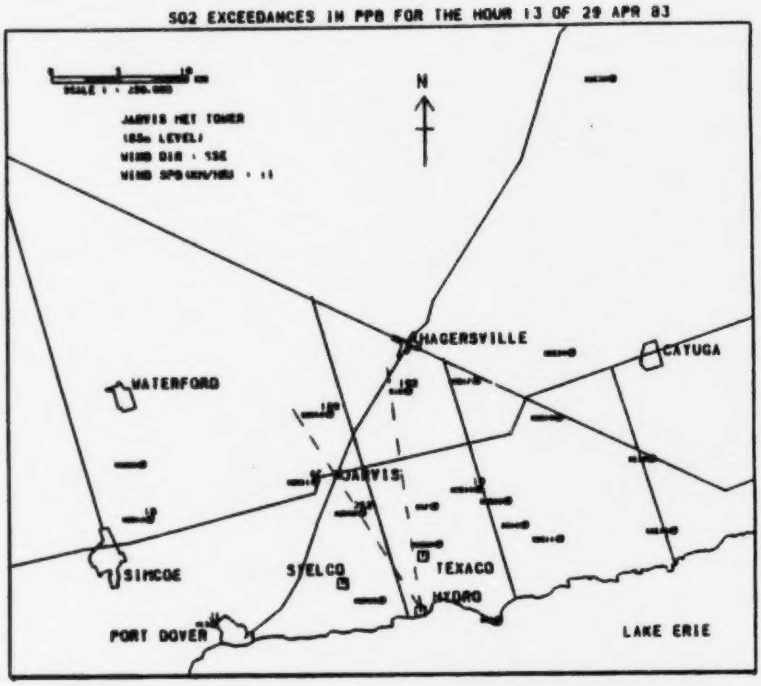




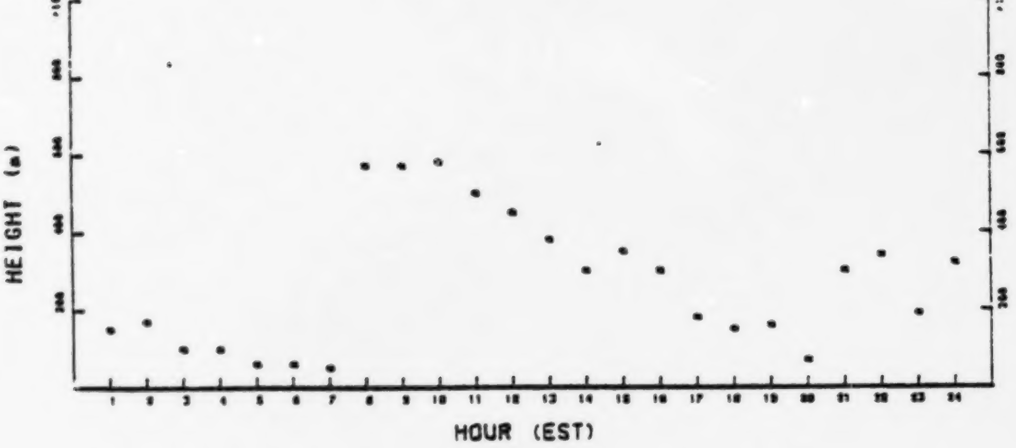
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 29 APR 83



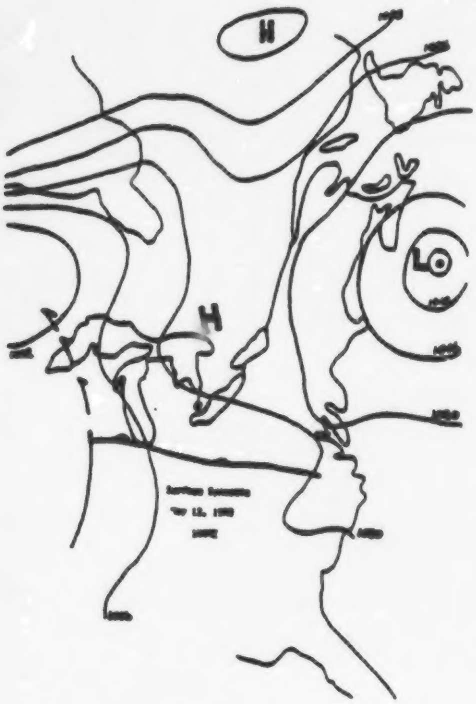
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 29 APR 83

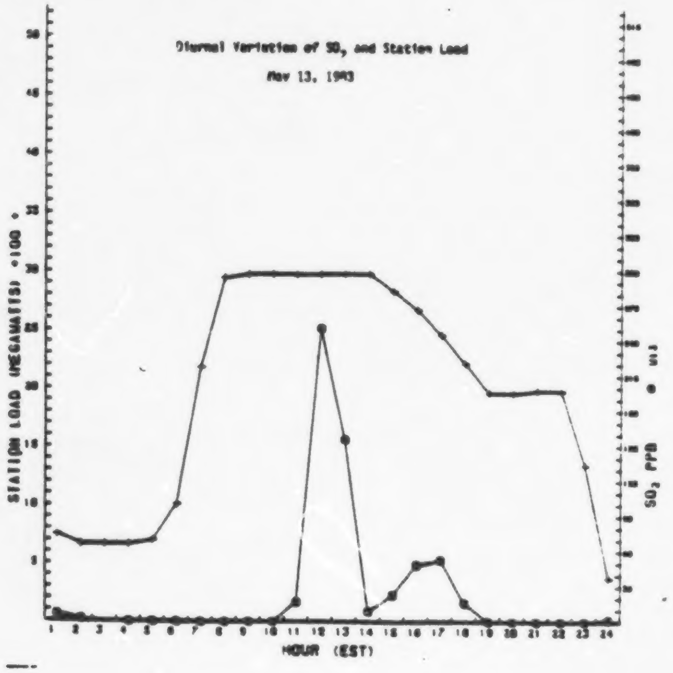


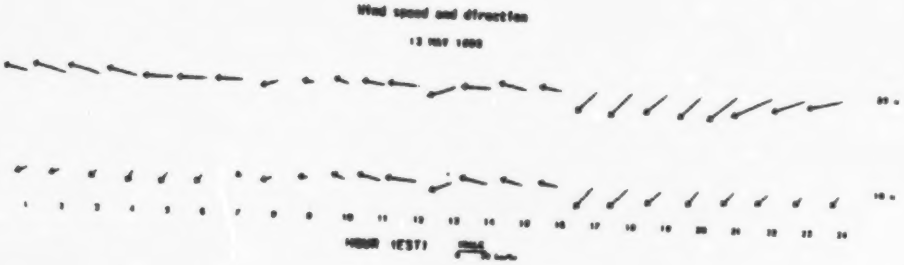
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 29 APR 1983



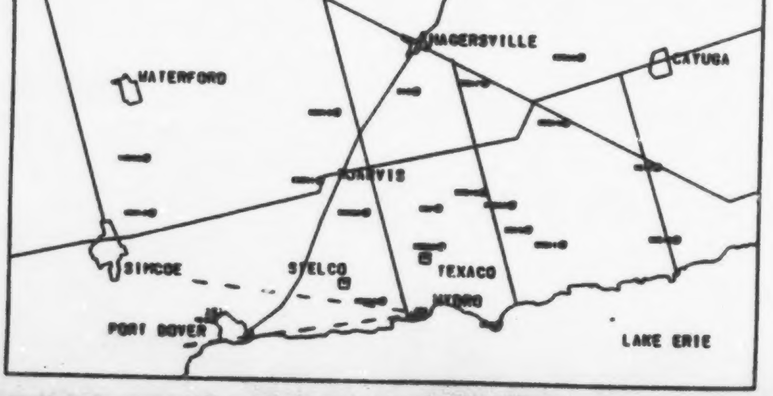
SO_2 EPISODE OF MAY 13,1983

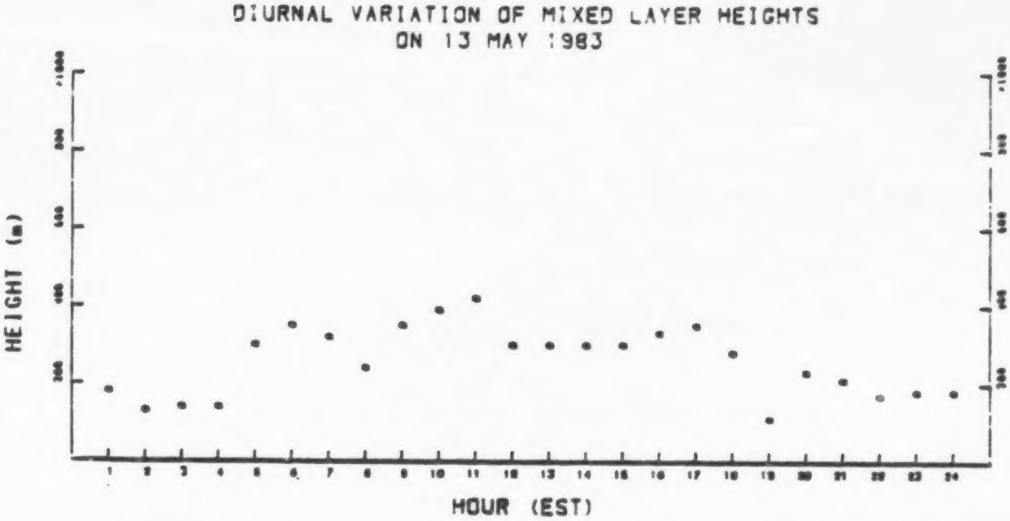






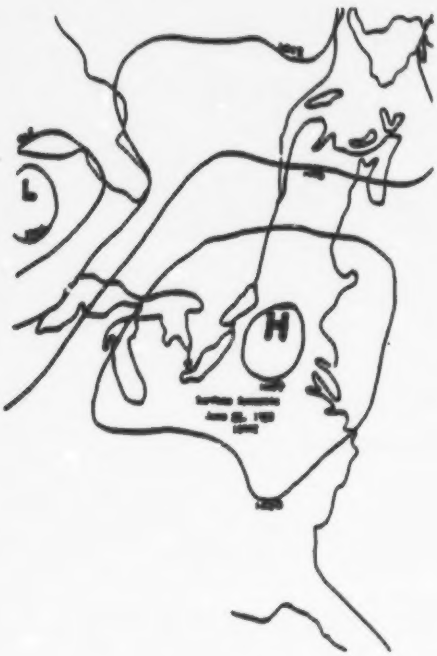
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 13 MAY 83

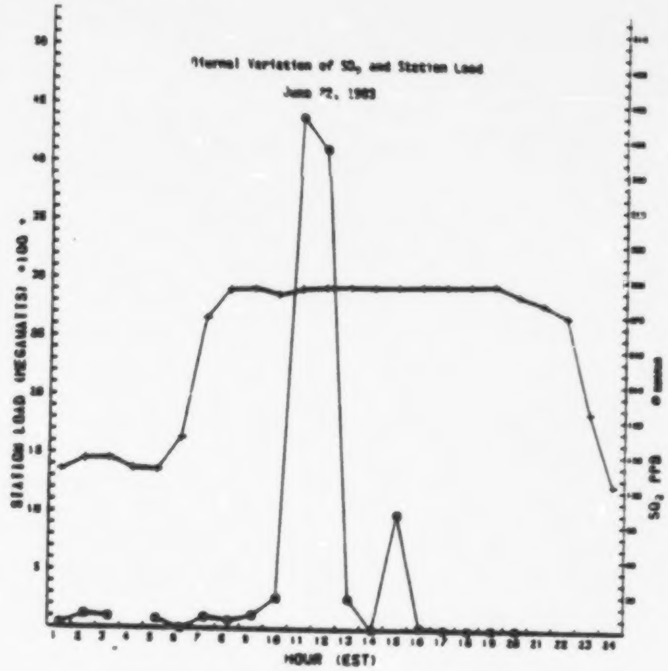


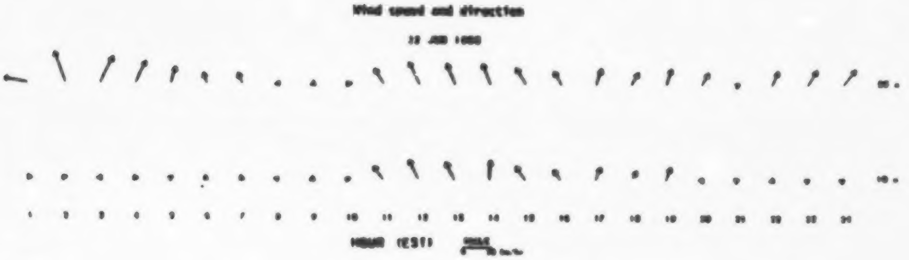


DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 13 MAY 1983

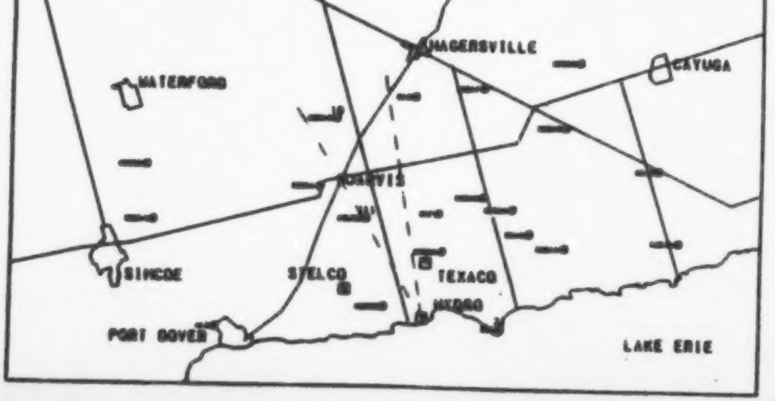
SO_2 EPISODE OF JUNE 22,1983



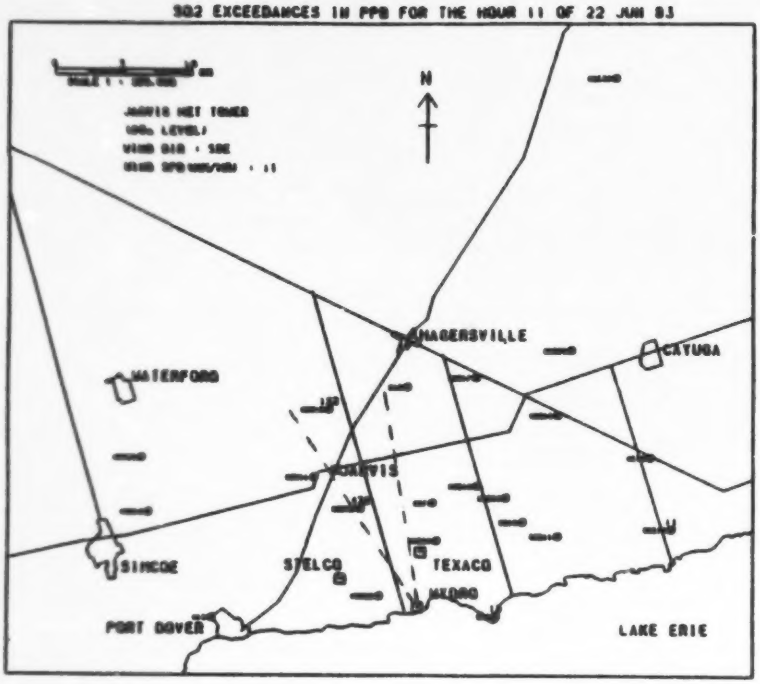




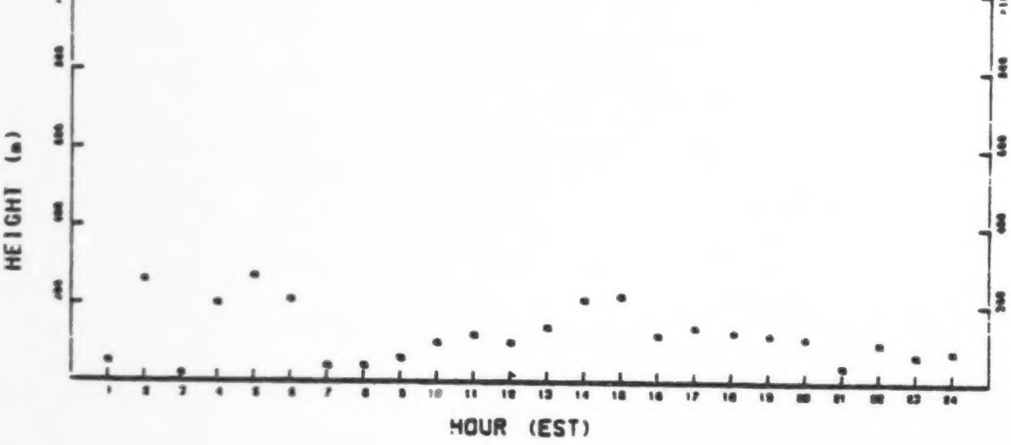
SO2 EXCEEDANCES IN PPB FOR THE HOUR 12 OF 22 JUN 83



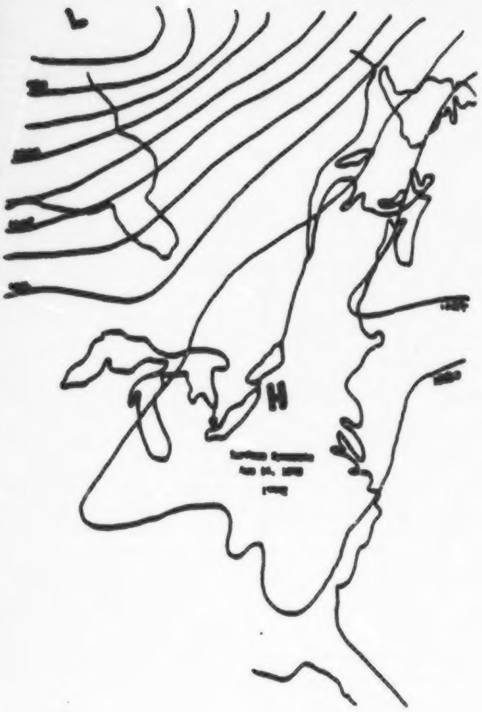
SO2 EXCEEDANCES IN PPB FOR THE HOUR 11 OF 22 JUN 83

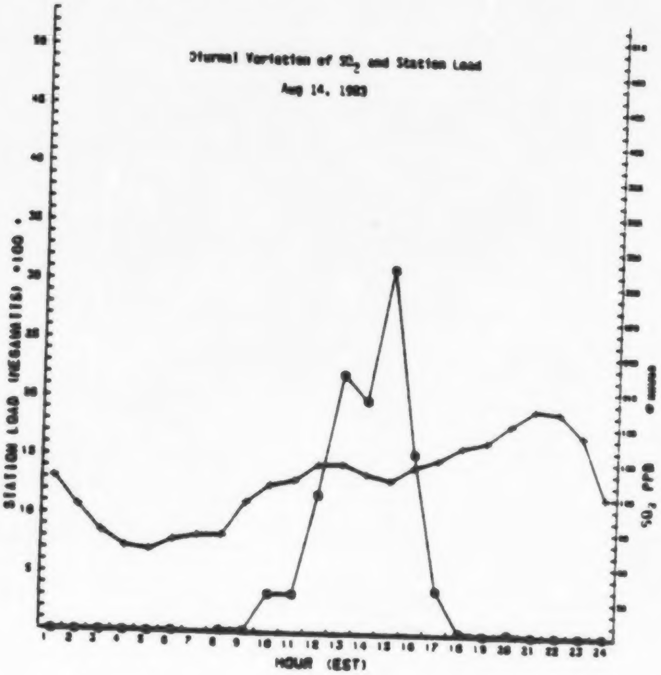


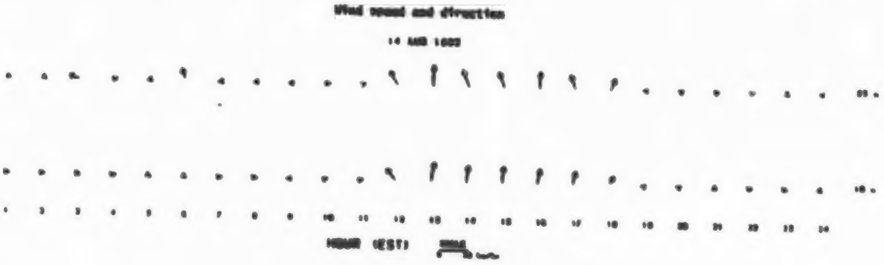
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 22 JUN 1983



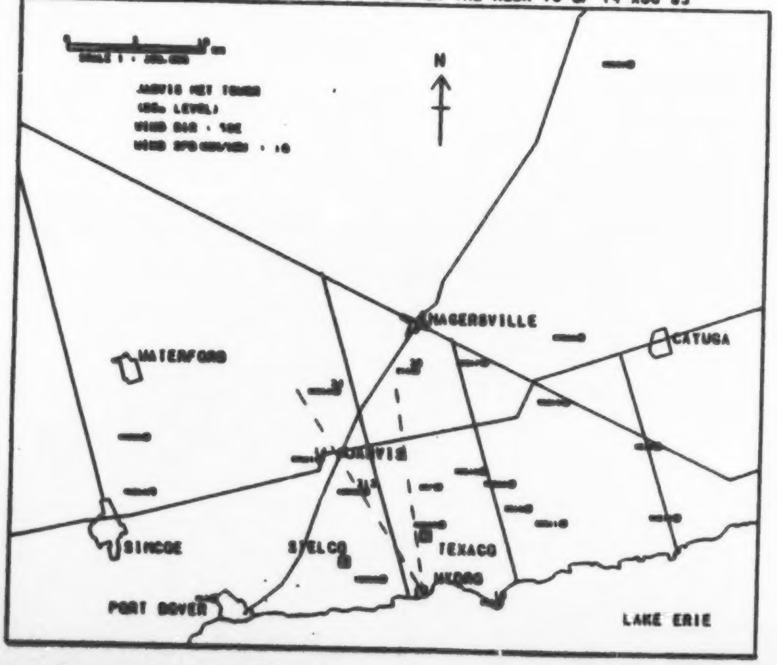
SO_2 EPISODE OF AUGUST 14,1983



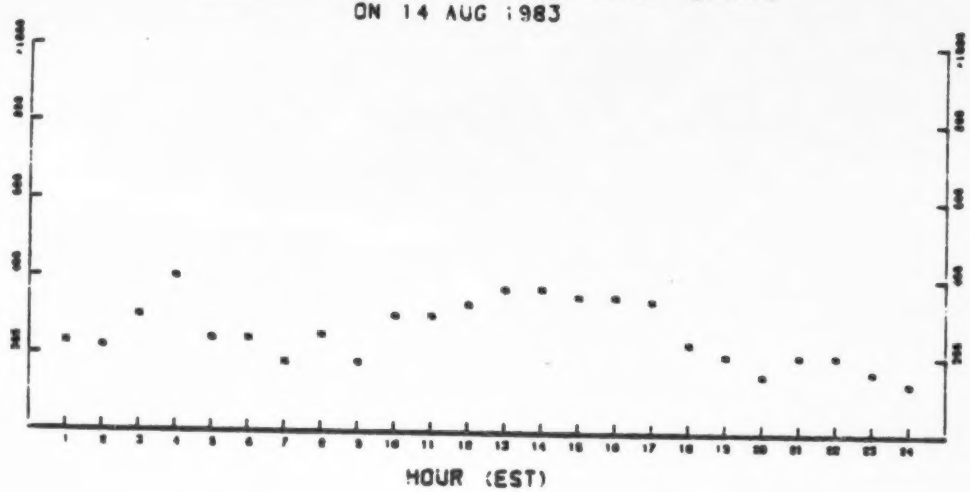




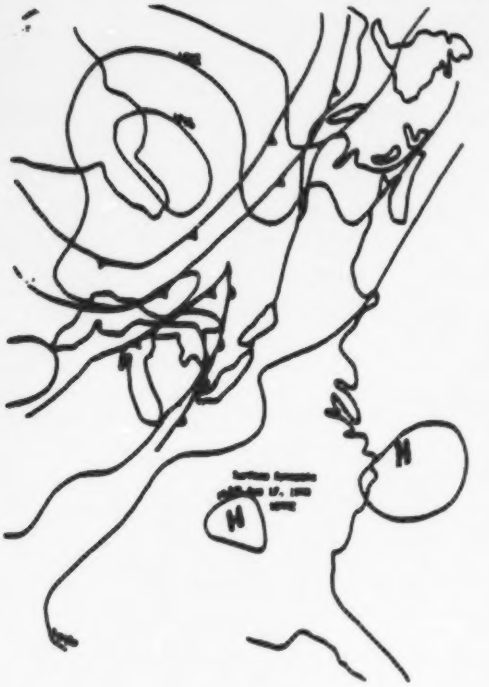
SO2 EXCEEDANCES IN PPB FOR THE HOUR 15 OF 14 AUG 83

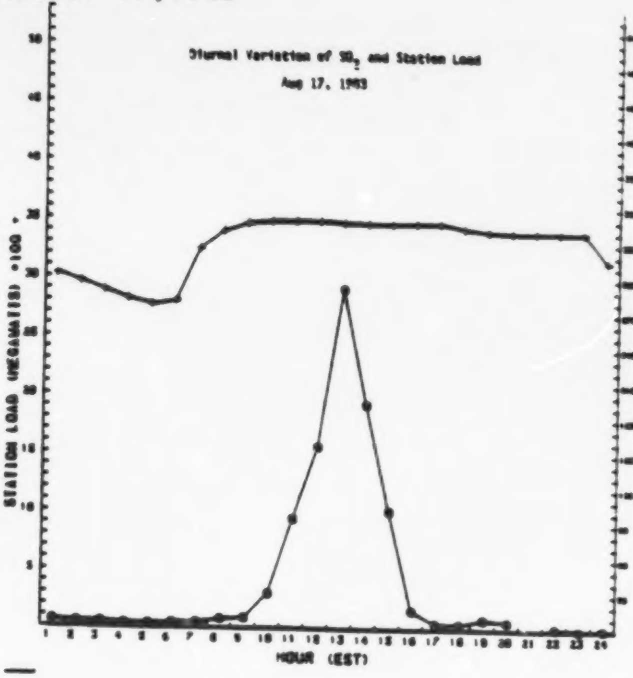


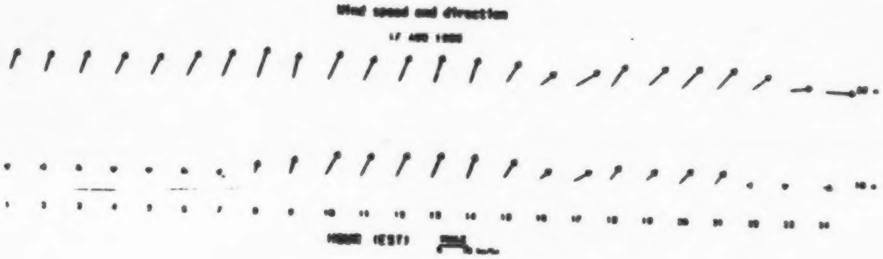
DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 14 AUG 1983



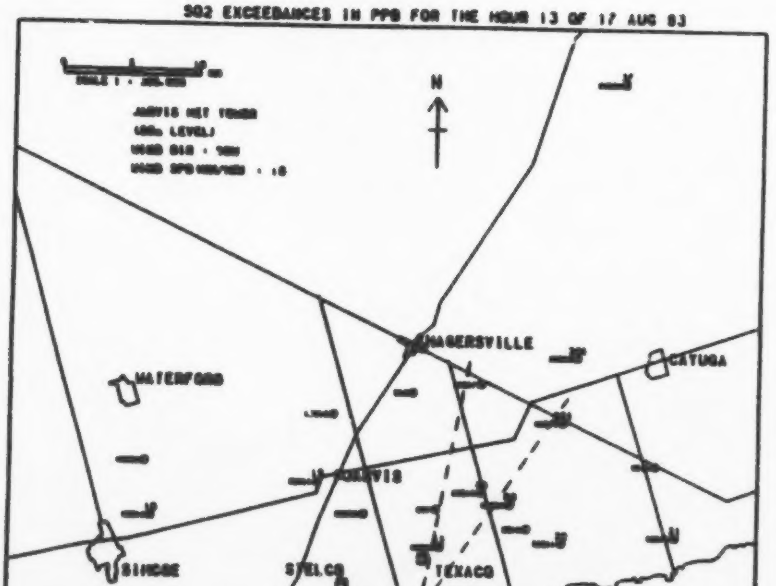
SO_2 EPISODE OF AUGUST 17,1983

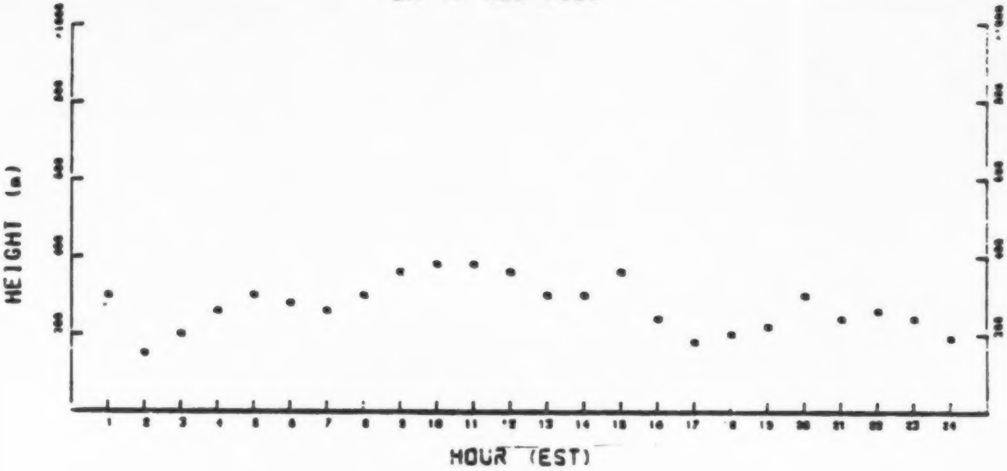




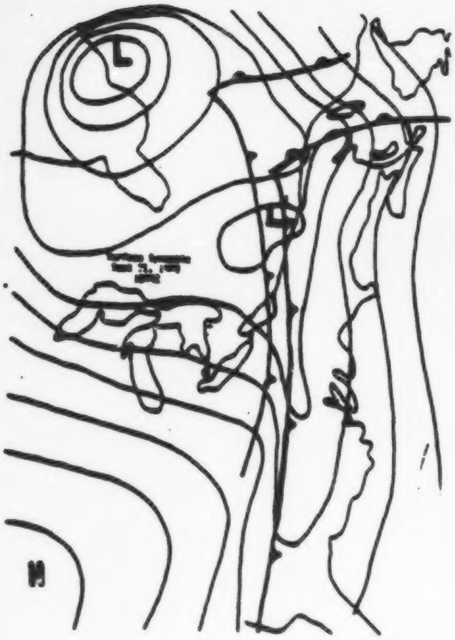


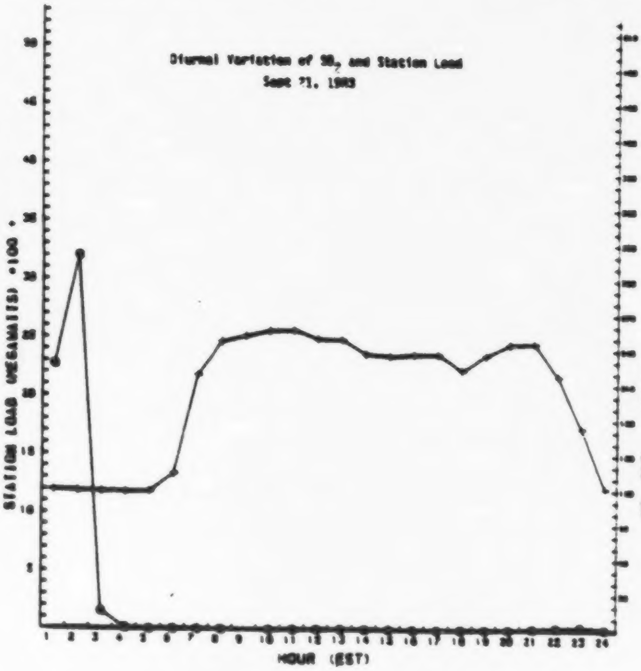
SO2 EXCEEDANCES IN PPB FOR THE HOUR 13 OF 17 AUG 83

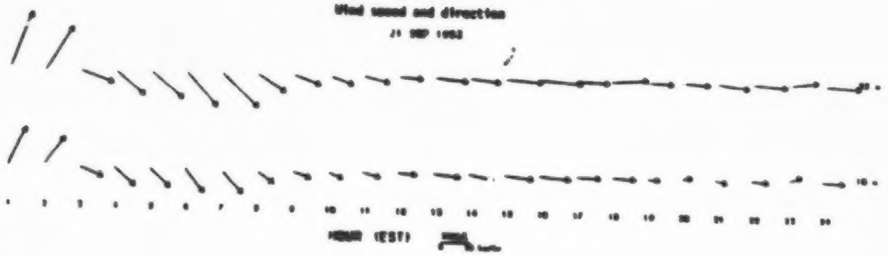



DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 17 AUG 1983

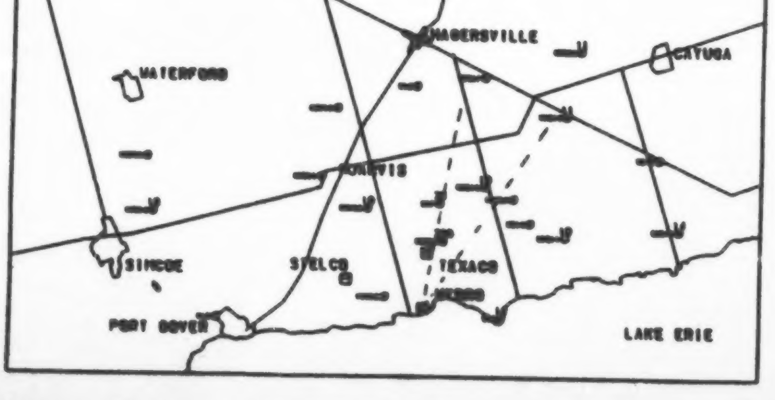
SO$_2$ EPISODE OF SEPTEMBER 21,1983



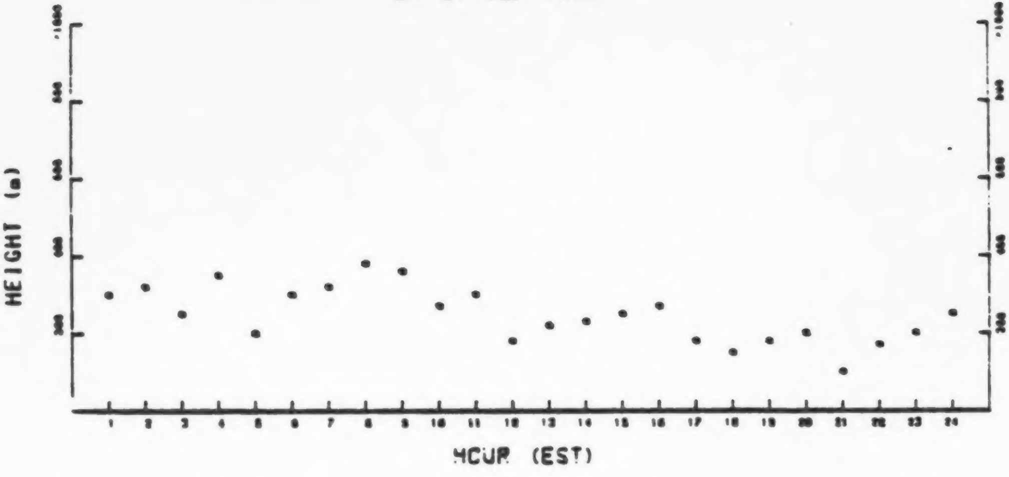




SO2 EXCEEDANCES IN PPB FOR THE HOUR 2 OF 21 SEP 83



DIURNAL VARIATION OF MIXED LAYER HEIGHTS
ON 21 SEP 1983



POOR

QUALITY

ORIGINAL